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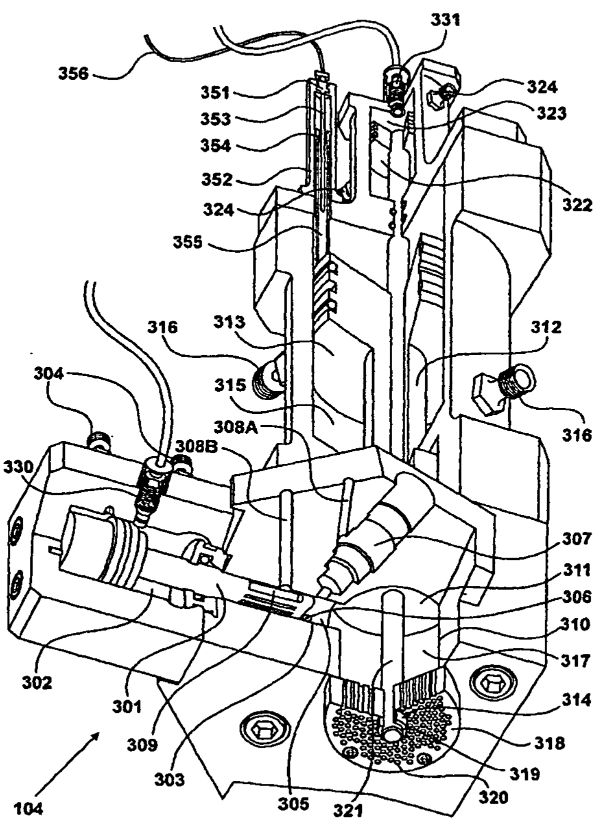
(54) Title: DISPENSING MATERIAL PRODUCED BY A CHEMICAL REACTION



(57) Abstract: Apparatus (104) for dispensing material produced by a chemical reaction between a first chemical reagent and a second chemical reagent. The apparatus comprises injection means (306) configured to produce a jet of the first chemical reagent and a jet of the second chemical reagent such that the jets collide to produce the material. The apparatus further comprises a storage chamber (317) and a closing device (321). The storage chamber is arranged to provide temporary storage space for the material, and it has an inlet for receiving said material and an outlet (319) for dispensing the material. The closing device is moveable between a first position in which the material is prevented from passing through the outlet of the storage chamber, while allowing material to be received into the storage chamber through the inlet, and a second position in which the material is allowed to be dispensed through said outlet.

WO 2004/035283 A1

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Dispensing Material Produced by a Chemical Reaction

Background of the Invention

1. Field of the Invention

The present invention relates to apparatus for dispensing material produced by a chemical reaction between a first chemical re-agent and a second chemical re-agent. The dispensed material may be foam-like or elastomeric. Preferably, the material is in a fluid state allowing it to be cast and then cured into a substantially solid construction.

2. Description of the Related Art

Foam-like material such as polyurethane is produced in situ so that it expands and sets into required shapes. A first chemical re-agent may be a diol and a second chemical re-agent may be a diisocyanate. In addition, small amounts of water are added to the reaction mixture during the polymerisation process to produce carbon dioxide gas that acts as the foaming agent.

High pressure systems are known in which the chemical re-agents are brought into contact under high velocity having been released from respective high pressure nozzles. High pressure systems of this type produce good quality polyurethane foam and require minimal maintenance. However, a problem with these systems is that output rates tend to be relatively high and attempts to scale down output production by reducing the size of the apparatus, and thereby reducing the volume of material released from the respective nozzles, have introduced further engineering difficulties.

Low pressure systems are known that use mechanical mixing operations and are thereby capable of operating at lower output rates/volumes. However, low pressure systems introduce further problems in that the quality of the mix tends to be lower than that produced by high pressure systems and organic solvents are required on a regular basis to effect the cleaning of a mixing chamber. In both of these known systems the rate of foam production is controlled by controlling the flow of the individual re-agents.

A further problem may be encountered with existing high pressure systems where injection into a mould is required. If the mould resists flow of material from the mixing head, a consequential build-up of fluid pressures within the system can prove catastrophic to production.

Brief Summary of the Invention

According to an aspect of the present invention, there is provided apparatus for dispensing material produced by a chemical reaction between a first chemical reagent and a second chemical reagent, comprising: injection means configured to produce a jet of said first chemical reagent and a jet of said second chemical reagent such that said jets collide to produce said material; a storage chamber arranged to provide temporary storage space for the material, said storage chamber having an inlet for receiving said material, and an outlet for dispensing the material; and a closing device moveable between a first position in which the material is prevented from passing through said outlet and a second position in which the material is allowed to be dispensed through said outlet.

By providing for the temporary holding of reacting material, it is possible for the material to be produced at a first high rate thereby making use of preferred high pressure techniques. Therefore the foam-like material may be dispensed at much lower rates, consistent with low pressure systems while taking advantage of the improved mixing qualities of the high pressure system and without requiring environmentally unfriendly organic solvents for cleaning purposes.

Alternatively, the temporary storing of reacting material after production has finished, allows the stored material to be subjected to high pressures required for injection into moulds.

Brief Description of the Several Views of the Drawings

Figure 1 shows a facility for the production of polyurethane items such as air filters;

Figure 2 illustrates a dispensing head for dispensing material;

Figure 3 shows a cut-away view of the dispensing head **104**, providing details of its internal structure;

Figure 4 shows an example of a chemical reaction for producing foam-like polyurethane;

Figure 5 shows a schematic diagram illustrating the flow of chemical reagents within the apparatus of *Figure 1*;

Figures 6A to *6E* illustrate the first mode of operation of the mixing head **104**;

Figures 7A to 7F illustrate a second mode of operation of the mixing head **104**;

Figure 8 shows a flow chart providing an overview of the operation of the computer control system **105** for controlling the production and dispensing of material;

Figure 9 shows the step **805** of initialising the apparatus;

Figure 10 shows the step **810** of putting the apparatus into stand-by mode;

Figure 11 shows the first mode of operation of the mixing head **104**, represented by step **807**, and illustrated by *Figures 6A* to *6E*;

Figure 12 shows the step **1106** of generating the required weight of material;

Figure 13 shows the purge cycle represented by step **1110;**

Figure 14 shows the second mode of operation of the mixing head **104**, represented by step **808**, and illustrated by *Figures 7A to 7F*;

Figure 15 shows the step **1409** of dispensing material;

Figure 16 illustrates automatic operation of the mixing head following power failure; and

Figures 17A and *17B* show, in cross section, an alternative mixing head **1704** embodying the present invention.

Written Description of the Best Mode for Carrying Out the Invention

Figure 1

Apparatus used for the production of a material by high pressure mixing of chemical reagents is shown in *Figure 1*. For the purpose of providing an illustration, the apparatus of *Figure 1* is used for the production of polyurethane items such as air filter cartridges for vehicles. Polyurethanes, and similar materials, have many applications in situations

where flexible light-weight materials are required.

The apparatus comprises a first storage container **101** containing a first stored chemical component, and a second storage container **102** in which a second chemical component is stored. Pumping devices **103** provide for circulation of the chemical components to a dispensing head **104** at high pressure. Reacted polyurethane foam is dispensed from the head **104** and the overall operation of the device is controlled by a computer system **105**. The dispensing head **104** is suspended from a boom **107**, which also supports electrical cabling, hydraulic pipes, and pipes carrying the two chemical components to the dispensing head **104**. A control unit **109** mounted on the dispensing head **104**, is provided to allow a human operator, such as operator **108**, to input commands to the computer system **105**.

In the present example, the dispensing head is manoeuvred by the operator **108** into position to inject the dispensed polyurethane into each of the moulds **110**. Each mould in this example requires a relatively small amount of polyurethane, i.e. twenty-five grams, and conventionally, due to the difficulties in producing such small quantities with high pressure systems, the tendency would have been to use a low pressure system with the disadvantages previously discussed. However, the apparatus of *Figure 1* allows relatively small quantities of polyurethane to be dispensed, at relatively low rates, while at the same time allowing materials to be reacted at high pressure, thereby improving quality and removing the need for cleaning procedures using organic solvents.

When manufacturing other items which require even smaller quantities of polyurethane, e.g. five grams, the manoeuvring of the

dispensing head is preferably performed by a robotic arm or other electromechanical manipulator. This is because the repositioning must be performed within time limits determined from the rates at which the chemicals react to form the polyurethane.

In addition to electro-mechanical manipulation of the dispensing head, moulds may be automatically moved into position below the dispensing head.

In the present example, only relatively low pressures are required to inject the dispensed material into the moulds. However, when moulds are used which have a small runner system, and consequently high pressure injection into the mould is required, the dispensing head may be clamped to the mould to avoid the foam pressure pushing the head out of position.

Figure 2

The dispensing head **104** for dispensing material, and the associated control unit **109** are illustrated in *Figure 2*. The dispensing head receives the first chemical reagents via pipe **201**, and a second pipe **202** allows it to be returned to the first storage container **101**. Similar pipes are provided for the supply of the second reagent to the other side of the dispensing head.

The head **104** is also supplied with pipes carrying hydraulic fluid, such as pipe **203**. Hydraulic pressure is used to energise the moving components of the dispensing head **104**, and the purpose of the hydraulic fluid will be described in detail below.

The control unit **109** has a display unit **204**, in the form of a liquid crystal display, which is used to present information to a user such as human operator **108**. The control unit **109** also has several button switches

205, 206, 207, 208, 209, and **210**. Buttons **210** and **209** allow an operator to scroll up and down through pre-programmed cycles stored within computer system **105**, and displayed on display unit **204**. Each cycle is defined by the weight of material produced in each production event, the ratio of the two chemical reagents used to produce material, the weight of material dispensed in each dispensing event, and the number of dispensing events. (The ratio of the reagents is adjusted to provide a required change in the properties of the generated material. The ratio is typically adjusted by less than plus or minus ten percent, by adjusting the ratio of the reagent injection pressures within allowed tolerances). In addition, for certain quantities of dispensed material, the cycle is also defined in respect of dispensing pressure and/or dispensing rate.

After selection of a particular cycle using buttons **209** and **210**, cycle start button **208** is pressed to start a production/dispensing cycle. If the operator **108** needs to stop production, the cycle stop button **207** is depressed, or if the apparatus must be shut down in an emergency, emergency stop button **206** is depressed.

When the dispensing head is used manually, as shown in *Figure 1*, the operator **108** depresses a manual dispense button **205** to indicate to the computer system **105** that the next dispensing event of the cycle should be performed. In cases where manoeuvring of the dispensing head **104** is automated, the head **104** receives a "dispense signal" from the electromechanical manipulator when correct positioning has been achieved.

Figure 3

A cut-away view of the dispensing head **104**, providing details of its internal structure, is shown in *Figure 3.* The dispensing head **104** has a production piston **301**, which has a rear end located within a hydraulic cylinder **302** and a front end located within a material production cylinder **303**. The piston **301** is moved between its fully forward and fully retracted position at high speeds by means of hydraulic pressure applied via hydraulic fluid connectors **304**.

In the retracted position, illustrated in *Figure 3*, the front face of the piston **301** and the wall of the production cylinder **303** define a production chamber **305** with a volume of approximately one cubic centimetre. During production, the first and second chemical reagents are injected at high pressure into the production chamber **305** via a respective one of two jets. The nozzle **306** of one of the jets is shown in *Figure 3*, while the location of the second jet is indicated at **307**. The jets are arranged so that each of the chemical reagents enters the production chamber as a jet of liquid and violently collides with the other jet of liquid at high velocity. This provides efficient mixing of the two reagents and the resulting chemical reaction produces dispensable material (for example polyurethane foam). This type of high pressure mixing/production is known in the art.

Inlet duct **308A** allows chemical reagent to be supplied to the jet located at **307**, while outlet duct **308B** allows the same unreacted reagent to be removed from the mixing head **104**. (Similar inlet and outlet ducts are provided for the other jet.) A pair of closed ended slots **309** are provided in the piston **301** so that when the piston **301** is in its forward position, the chemical reagents may be circulated at high pressure through the inlet

ducts, such as **308A**, through their respective jets, through a respective slot **309**, and out through an outlet duct, such as **308B**. By this means, the reagents may be circulated through the jets at high pressure prior to mixing to allow the mixing pressure to be established and stabilised. The production piston **301** is then retracted at high speed, and the high pressure jets of reagent collide. When a required weight of material has been produced, the piston **301** is moved forwards at high speed to stop production, and the chemical reagents are again allowed to circulate through slots **309**. Thus, the high pressure jets are switched on and off very quickly without unacceptable pressure build up in chemical reagent supply circuits.

The production chamber has one end open to a dispensing cylinder **310** which contains the lower end **311** of a dispensing piston **312**. The upper end **313** of the piston **312** is located in a second hydraulic cylinder **315** so that the piston **312** may be pushed downwards or upwards by applying the necessary fluid pressure via hydraulic connectors **316**.

In retracted positions, as shown in *Figure 3*, the front face of the piston **312** and the wall of the dispensing cylinder **310** define a dispensing chamber **317**. A cap **318** provides a lower wall to the chamber **317** at its lower end. At its centre, the cap **318** has a nozzle **314** defining a circular aperture which provides an output port **319** through which material in chamber **317** is dispensed. During operation material generated in the production chamber **305** passes through its open end into the dispensing chamber **317**. Thus the open end of the production chamber **305** defines an inlet for the dispensing chamber **317**.

In the preferred embodiment, the tolerance between the dispensing piston **312** and the inside wall of the dispensing chamber **317** is between ten microns and fifteen microns. Preferably, the diameter of the lower end **311** of the dispensing piston **312** will be between forty and seventy millimetres providing a dispensing force of approximately 11 tonnes.

An array of smaller ducts **320** are provided through the cap **318**, such that each duct **320** provides a passage from the chamber **317** to an outer surface of the cap. Over time, there is a tendency for fully reacted material to build up on the inner surface of the cap **318**. This unwanted material is periodically removed by extruding it through the ducts **320** under pressure of the dispensing piston **312**. This purging operation will be described below in further detail with reference to *Figure 13*. However, during general use, it is arranged for the ducts **320** to be full of solid reacted material which provides a plug to prevent leakage of un-reacted material.

The ducts **320** are preferably tapered such that they have a larger diameter at the inner surface and a smaller diameter at the outside surface of the cap. This shape provides assistance when the extruding operation is performed.

Furthermore, the inner surface of the cap **318** is shaped such that it has raised portions, each providing a cutting edge, located between the ducts **320**, and angled surfaces which slope down towards the ducts **320**. In the present embodiment this is achieved by providing the ducts with intersecting countersinks. During the extrusion process, the cutting edges provide assistance by cutting into the solidified material on the inner surface of the cap, the material is then forced into the countersinks whose angled surfaces funnel said material into the ducts **320**.

In an alternative embodiment, the inner surface of the cap **318** is provided with an array of V-shaped grooves which meet at their upper edges to provide cutting edges. The ducts **320** are spaced along the bottom of the grooves so that during the extrusion process the solid material tends to be cut by the cutting edges formed by the grooves, and funnelled by the sloping surfaces of the grooves towards the ducts. The grooves preferably extend radially outward from the output port **319**, deepening as they extend outward so that the cutting edges extend along their whole length.

In an alternative embodiment, the dispensing head **104** is provided with cooling means for cooling the cap **318**. Consequently, the rate of reaction of material within chamber **317** adjacent to the cap is retarded and the frequency of performing the purging cycle is reduced. Such cooling may be provided by circulating cooled liquid through additional pipes arranged in or adjacent to the cap **318**.

In an alternative embodiment, a disc having an array of apertures matching that of the cap **318** is rotatably mounted to the outer surface of said cap. Thus, the disc may be rotated to a first position in which the apertures of the disc and cap are aligned to allow the extruding operation to take place. Or, the disc may be rotated to a position in which the ducts **320** of the cap **318** are blanked off by the disc to prevent material escaping through said apertures during normal dispensing operations.

The dispensing piston **312** has a circular bore extending along its axis and an output control rod **321** is located within said bore. The upper end of the rod **321** is attached to a piston **322** located within a third hydraulic cylinder **323**, and, thus, by applying hydraulic pressure to the piston **322** via hydraulic connectors **324**, the rod **321** may be moved

between a forward and a retracted position. In the retracted position, the lower end of rod **321** is located within the dispensing chamber **317**, and material located within said chamber may be dispensed through output port **319**. When the rod **321** is in its forward position, its lower end is located within the output port **319** and it has a sufficiently good fit within said port to prevent material within the chamber **317** from escaping. The output control rod **321** therefore provides a means of closing the output port **319**. However, in addition, it provides a means of clearing the output port of material.

Preferably, the output control rod **321** will have a diameter of eight to fifteen millimetres and the total area of contact between all moving surfaces will be sufficient to provide effective sealing but will not be so great as to create sticking problems.

During one mode of operation of the dispensing head **104**, material produced in chamber **305** is temporarily stored in dispensing chamber **317**, and accurate quantities of material are then dispensed by moving the dispensing piston forward by a controlled amount. For this reason, a signal relating to the position of the dispensing piston is generated and sent to the computer system **105** by a position sensor **351**.

The sensor **351** is a linear conductive plastic position transducer located in a housing **352** which extends from the upper end of the second hydraulic cylinder **315**. The sensor **351** has a conductive plastic portion **353** rigidly fixed to the upper end of the housing **352**, and a wiper **354** rigidly fixed to the upper end of a guide tube **355**. The guide tube is itself rigidly attached to the upper end **313** of the piston **312**, and thus, as the piston **312** moves up or down, the wiper **354** is moved in a corresponding manner

along the conductive plastic portion **353**. An electrical reference voltage is supplied to the sensor **351** and a voltage signal indicative of the wiper's position is received from the sensor by means of electrical cable **356**.

The guide tube **355** is dimensioned to slide up and down within housing **352** while limiting rotational movement of the piston **312**, and thus the sensor **351** is protected from potentially damaging bending forces. In the present embodiment the sensor **351** is a conductive plastic incylinder transducer with a stroke length of 150mm, manufactured by Variohm-Eurosensor Ltd. in the UK under reference number P6403-100-H003.

In use, the pistons **301** and **322** are required to be fully forward or fully retracted. In order to provide data to the computer system **105** informing of their status, the relevant cylinders are provided with proximity switches **330** and **331** respectively.

The apparatus includes a hydraulic power pack (not shown) capable of charging an accumulator to a pressure of two hundred bar for normal operation of the three hydraulic pistons within the mixing head. In addition, a hydraulic intensifier (not shown) is used to charge a second accumulator to a pressure of four hundred bar, for use when a purging operation is required to extrude unwanted solid material from the dispensing chamber.

Both the output control rod and the production piston are operated by a respective two-way hydraulic directional control valves. In the present embodiment the hydraulic control valves are manufactured by Atos with reference number DHI-0631/2-00. A requirement of the dispensing piston is that it may be moved forwards at controlled rates and/or under controlled pressure, and consequently, a proportioning valve controls its movement. In the present embodiment, the proportioning valve control is a proportional

valve (cetop3) series DLHZO, driven by electronic driver series E-ME-T-2H under the control of a closed loop controller series E-ME-K-PID, all manufactured by Atos.

In the present embodiment, the upper part **313** of the dispensing piston **312** has a diameter of 85mm, while the lower part **311** has a diameter of 50mm, and the output control rod has a diameter of 10mm. Thus, the surface area of the upper part **313** on which hydraulic fluid acts to force piston **312** down is more than twice the surface area of the lower part **311** which acts upon material in dispensing chamber **317**. As a result, the pressure applied to the material to dispense it, is more than twice the applied hydraulic pressure. For example, two hundred bar hydraulic pressure generates a pressure of approximately five hundred and seventy bar in the material being dispensed. This pressure increase can be used to advantage where high pressure injection into a mould is required.

In an alternative embodiment, colour is injected down the centre of the production chamber **301** so as to provide efficient mixing of colour pigments prior to the material being received within the output dispensing chamber **317**.

It is also possible to fit two (or more) production chambers to a single dispensing chamber thereby allowing two types of material to be dispensed from the same head in an alternating manner. Under these conditions, it is possible to recharge the dispensing chamber alternately from different production chambers such that the same head may dispense soft or hard material on alternate cycles, or different coloured material on alternate cycles. For instance, each production chamber may be supplied with a different polyol stream and a common isocyanate, such that the dispensing

chamber may be charged with, and dispense, different types of material in an alternating manner. Alternatively, one or more of the production chambers may be arranged to mix a colour pigment with the reagents, whereby the dispensing chamber may be charged with, and dispense, material of different colours in an alternating manner.

Figure 4

By way of example, a chemical reaction to generate material within dispensing head **104** is illustrated in *Figure 4*. In this case, the first and second chemical components are a diol **401** and a diisocyanate **402** which react to produce polyurethane **403**. Preferably, large diisocyanate molecules are employed as these are less hazardous.

Figure 5

A schematic diagram illustrating the flow of chemical reagents within the apparatus of *Figure 1*, is shown in *Figure 5*.

When the apparatus is not producing material, chemical reagents stored in storage containers **101** and **102** are circulated around a circuit at low pressure. Thus, the first chemical reagent stored in storage container **101** is circulated by a first pumping device **103A** through pipe **501A**, through a first stream distributor valve **502**, and back to the container **101** through pipe sections **501B** and **501C**. Similarly, the second chemical reagent stored in storage container **102** is circulated by a second pumping device **103B** through pipe **551A**, through a first stream distributor valve **552**, and back through pipe sections **551B** and **551C**.

Immediately prior to material production, the stream distributor valves are closed to prevent flow through pipe sections **501B** and **551B**. Consequently, the first chemical reagent is circulated through pipe sections **501A** and **501D** to the mixing head **104**, and when the production piston **301** is in its forward position, said reagent is returned via pipe sections **501E** and **501C** to the container **101**. Similarly, the second chemical reagent is circulated through pipe sections **551A**, **501D** and returned via pipe sections **551E** and **551C**. Thus, the chemical reagents are circulated through the jets within the mixing head and the required high pressures for mixing are established and stabilised.

When mixing begins, the production piston **301** is retracted and the first and second chemical reagents are mixed within production chamber **305** to generate new material, such as polyurethane foam. The newly generated material passes from the production chamber **305** into the dispensing chamber **317**, from which it is either dispensed immediately, in a first mode of operation, or after a short period of storage in a second mode of operation.

Figures 6A to 6E

The first mode of operation, of the mixing head **104** is shown schematically in *Figure 6A* to *6E*.

The mixing head **104** is shown in *Figure 6A* in its post-production configuration, and thus it is in a position to begin a new production cycle. Therefore, the production piston **301**, the dispensing piston **312** and the output control rod **321** are all in their fully forward positions. The mixing head has been used, or has been prepared for use in a manner to be

described below. Consequently, a layer **601** of solid fully reacted material exists between the dispensing piston **312** and the inner surface of the cap **318**, and which extends through the ducts **320**.

Within a predefined period prior to production of material, the chemical regents are circulated through inlets **308A** and **608A** through the respective jets and slots **309** in the production piston **301**, and out through outlets **308B** and **608B**.

The configuration of the mixing head immediately prior to production in the first mode is shown in *Figure 6B*. The dispensing piston **312** has been retracted to a pre-defined position to define the dispensing chamber **317**, and such that its lower end just clears the end of the production cylinder **303**. The output control rod **321** is retracted such that the output port **319** is open.

Production then takes place by the retraction of the production piston **301** as illustrated in *Figure 6C*. In this configuration, mixing and reaction of the chemical reagents takes place within production chamber **305**. Due to the high pressures and energies involved in the process, the newly produced material passes from the production chamber **305**, through dispensing chamber **317** and out through output port. Thus, in this mode, the mixing head produces and dispenses material simultaneously, in a similar manner to a conventional mixing head. However, in contrast to a conventional mixing head, the mixing head **104** has an output control rod **321** which is in line with the axis of the production chamber **305**. Consequently, the material expelled from production chamber **305** tends to strike the output control rod **321**, and this enhances mixing of the chemical reagents, particularly at the very start of production, when the two jets of

chemical reagents first collide.

When material has been produced for the required time, and thus the required quantity of material has been produced, the production piston is moved to its forward position to end production. This situation is illustrated in *Figure 6D*, in which production of material has ended, but some material still occupies the dispensing chamber **317**. The dispensing piston **312** is immediately moved forwards to dispense the remaining material through the output port **319**.

Figure 6E shows the status of the mixing head after the dispensing piston **312** has been moved fully forward. Under the very high pressure which may be exerted by the dispensing piston, only a very small quantity of liquid material remains trapped between the dispensing piston **312** and the upper surface of the solid material layer **601**. A small quantity of liquid material is inevitably trapped, but, after fully reacting, this merely adds to the thickness of the solid material layer **601**.

Immediately after moving the dispensing piston to its fully forward position, the output control rod **321** is also moved to its fully forward position to eject the remaining material from the dispensing chamber output port **319**. After this movement, the mixing head is once again in its post-production configuration illustrated in *Figure 6A*.

Figures 7A to 7F

A second mode of operation of the mixing head **104** is illustrated by *Figures 7A to 7F*.

The mixing head **104** is shown in *Figure 7A* in its post-production configuration. Thus, *Figure 7A* is merely a copy of *Figure 6A*, provided to

facilitate illustration of the second mode. Since the mixing head is between production cycles, the production piston **301**, the dispensing piston **312** and the output control rod **321** are each in their fully forward positions.

In the second mode of operation, material is produced and stored in the dispensing chamber and then, immediately after production has finished, the stored material is dispensed. Therefore, before production of material begins, the dispensing piston is retracted to provide the dispensing chamber **317** in which material is temporarily stored. The amount of backward movement of the dispensing piston **312** from the upper surface of the solid layer **601** is calculated to provide a suitable sized space for the material being produced.

It should be noted that the fully forward position of the dispensing piston, as shown in *Figure 7A*, varies with use, because the solid material layer **601** increases in thickness during each dispensing cycle. However, the position sensors on the dispensing piston provide information to the computer system **105** of its fully forward position, and thus its backward movement is calculated from this.

The mixing head **104** is shown in *Figure 7B* after the dispensing piston **312** has been retracted by the calculated distance from the upper surface of the solid layer **601**. The output control rod **321** is still located within the output port **319** and consequently, the backward movement of the dispensing piston **312** has left a vacuum within dispensing chamber **317**.

Having established an evacuated dispensing chamber, the production piston is retracted to start production of material. The configuration of the mixing head **104** during material production is shown in

Figure 7C. The material produced in chamber **305** tends to be forced into the dispensing chamber by the high energy of the material, and this movement is assisted by the vacuum within the chambers **305** and **317**.

When production has taken place for the required period to generate the required weight of material, the piston **301** is moved forward to end production, as shown in *Figure 7D*. As in conventional mixing heads, the production piston **301** also clears the production chamber of remaining material.

However, unlike in a conventional mixing head, the newly generated material is temporarily stored. It has been found that for materials such as polyurethane, which are conventionally produced and dispensed simultaneously, a finite time period exists in which the material may be stored and dispensed. This period of time is typically less than twenty seconds, but it is utilised by the present invention to enable greater versatility in the manner in which the material is dispensed.

To allow dispensing to take place, the control rod **321** is withdrawn to open the output port **319**, as shown in *Figure 7E*. The material is then dispensed by moving the dispensing piston **312** forward. The dispensing piston may be moved at a controlled rate, under controlled pressure, and by a controlled distance. Thus, for example, where the mixing head is used to supply polyurethane to a mould with a very small runner, the very high pressures which may be applied by the dispensing piston **312** ensure that the material flows as required. Alternatively, for example, if the mixing head is used to fill several small moulds with only a small quantity of polyurethane, the dispensing piston is moved forward by a calculated distance to dispense said small quantity to a first mould, the mixing head is

moved to a second mould and then a second small quantity is dispensed to the second mould, and so on. It should be noted that while the mixing head is moved between moulds, the output port **319** is temporarily closed by control rod **321** to prevent leakage of material from the dispensing chamber **317**.

In a case such as this, because the production of material has been separated from the dispensing operation, the rate at which material is dispensed may be different from the rate of production, the pressure of dispensing may be varied without adversely affecting production, and the individual quantities that are dispensed to each mould may be a fraction of the material produced.

Figure 7F shows the mixing head after the dispensing piston **312** has been moved forward by a calculated amount to dispense a small quantity of material to a small mould. Similar movements of the dispensing piston are subsequently made to dispense similar quantities to a number of further moulds, and to bring the dispensing piston to the fully forward position. The output control rod **321** is then brought forward to close and clear the output port **319**, and the mixing head is, once again, placed in the configuration shown in *Figure 7A.*

Figure 8

Operations performed by the computer control system **105** (or similar control system, such as a programmable logic controller, or a micro-controller) in order to control the production and dispensing of material are illustrated by the flow charts shown in *Figures 8* to *15*.

An overview of the operation of the control system **105** is shown in *Figure 8*. Step **801** represents a set-up procedure in which the apparatus receives inputs defining a production and dispensing operation, or possibly an indication to shut down. The inputs may be user inputs made at control unit **109** or computer system **105** directly, or alternatively may be received from some other external controlling apparatus such as a computer. The inputs may define a new operation in terms of the weight of each dispensed unit, the total number of units to be dispensed, the rate of dispensing, and the pressure under which the material is dispensed. In some applications the ratio of reagents may also be adjusted. For example, when producing polyurethane, the mix of diol and diisocyanate may be adjusted as the application requires. Thus, the ratio of reagents is also specified when defining a new dispensing operation. Alternatively, the inputs may merely select an pre-defined production cycle using control unit **109**, and indicate its start.

After receiving inputs at step **801**, a question is asked at step **802** to determine if apparatus shut down has been indicated, and, if it has, then the apparatus is shut down at step **811**. Otherwise, step **803** is entered where it is determined whether a dispensing cycle start has been indicated. If not then the process returns to step **801** and steps **801** to **803** are looped around until either of the questions at steps **802** or **803** is answered yes.

If the question at step **803** is answered yes then a question is asked at step **804** as to whether the apparatus has been initialised. If it has, then step **806** is entered directly but otherwise the apparatus is initialised at step **805** before step **806** is performed.

At step **806** it is determined whether or not the volume of each unit of material to be dispensed is greater than the maximum volume of the dispensing chamber **317**, and if it is, then material is produced and dispensed in the first mode of operation illustrated by *Figures 6A to 6E*, at step **807**. Alternatively, material is produced and dispensed in the second mode of operation illustrated by *Figures 7A to 7F*, at step **808**.

Following steps **807** or **808** a question is asked at step **809** as to whether another dispensing operation is to be performed, and if so then the process returns to step **801** directly. If another operation is not due to be performed then the apparatus is put into a stand-by mode at step **810** before step **801** is re-entered. Depending upon inputs received at step **802** the apparatus may then perform further dispensing operations or be shut down.

Figure 9

The step **805** of initialising the apparatus is shown in detail in *Figure 9*. Firstly at step **901** the pumps **103** are started, and at step **902** the hydraulic power pack is started in order to charge the first of two accumulators to a pressure of two hundred bar. At step **903** the hydraulic intensifier is started to store pressure of four hundred bar in the second accumulator.

At step **904** the stream distribution valves **502** and **552** are closed causing the circulating chemical reagents to be pumped at high pressure through the jets in the mixing head **104**. In order to ensure good mixing of the reagents, a stable high pressure of typically one hundred and fifty bars must be established before production begins. For this reason a short

period of time, of typically five seconds, is provided for the establishment of this pressure before production is allowed. To measure this period, a high pressure recycle timer is started at step **905**.

Figure 10

The step **810** of putting the apparatus into stand-by mode is shown in *Figure 10*. Firstly at step **1001** the stream distribution valves **502** and **552** are opened allowing the chemical reagents to circulate around the low pressure circuit instead of through the mixing head jets. The pumps **103** are then switched off at step **1002**, and the hydraulic power pack is switched off at step **1003**. The pressure stored in the accumulators is retained for later use.

Figure 11

The first mode of operation of the mixing head **104**, represented by step **807**, and illustrated by *Figure 6A* to *6E*, is shown in greater detail in *Figure 11*. Firstly, at step **1101**, the output port is opened by retracting the output control rod **321**. Specifically, the respective two-way hydraulic directional control valve is de-energised to move the output control rod back, and the retracted position is confirmed by proximity sensor **331**. Then at step **1102** the dispensing piston is moved back under the control of the proportioning valve to a position which will allow material to flow from the production chamber **305** into the dispensing chamber **317**, as shown in *Figure 6B*.

At step **1103** it is determined whether or not the high pressure recycle timer, started at step **905**, has timed out. When it has the process

moves on to step **1104** where it is determined whether or not a signal has been received indicating that dispensing is required. This signal may be a user input by button **205** or a signal from an electro-mechanical manipulator. If the dispense signal has not yet been received, a wait state is entered at step **1105** before the question at step **1104** is asked again. Thus this wait loop continues until the dispense signal is received, at which time step **1106** is entered.

At step **1106** the required weight of material is produced and simultaneously dispensed. At step **1107** the material remaining in the dispensing chamber is also dispensed by bringing the dispensing piston **312** fully forward under proportioning valve control, using pressures of up to two hundred bar. The two-way hydraulic directional control valve for the output control rod **321** is then energised to close the output port **319**. After confirmation of the closure is received from the proximity sensor **331**, a question is asked at step **1109** as to whether the thickness of the solid layer of material **601** has become larger than a predetermined threshold value. If it has, then a purge cycle is performed at step **1110** before step **1111** is entered, but otherwise step **1111** is entered directly.

At step **1111** a question is asked as to whether the current operation has been completed. The current operation may comprise of several cycles of dispensing units of material, and so further dispensing cycles may still be required. If the current operation has been completed then step **807** is completed and step **809** is entered. Otherwise, steps **1101** to **1111** are repeatedly repeated until the question at step **1111** is answered yes.

Figure 12

The step **1106** of generating the required weight of material is shown in further detail in *Figure 12.* Initially at step **1201** the two-way hydraulic directional control valve for the production piston **301** is energised to move said piston backwards. Then a question is repeatedly asked at step **1202** as to whether the proximity switch **330** has confirmed full back stroke of the production piston. When this question is answered yes, a mixing weight timer is started at step **1203.** A question is then asked at step **1204** as to whether the mixing has taken place for the required time to generate the required weight of material. If answered no, this question is repeated, and material is generated, until it is answered yes. When this question is answered yes, the hydraulic control valve for the production piston is de-energised at step **1205** to move said piston forward and stop production. When the proximity switch has confirmed that the production piston is fully forward, at step **1206**, step **1106** is completed.

Figure 13

The purge cycle represented by step **1110** is shown in further detail in *Figure 13*. At the start of the purge cycle, the mixing head is configured as shown in *Figure 6A*. Thus, the pistons **301** and **312** and control rod **321** are all fully forward. However, the dispensing piston **312** is separated from the cap **318** by a layer of solid material **601** which has become thicker than desired. For this reason, the hydraulic intensifier pressure of 400 bar from the second accumulator is used to move the dispensing piston **312** under slow speed control, at step **1301**. This has the effect of extruding the solid material layer through ducts **320**. It is required that the solid layer be

reduced to a thickness of typically 2mm by this process, and therefore a question is asked at step **1302** as to whether the dispensing piston has reached a predefined position. If it has not, then extrusion continues at step **1303** before the question at step **1302** is asked again. Thus, material is extruded until the question at step **1302** is answered yes, whereupon the hydraulic pressure applied to the dispensing piston **312** is reduced at step **1304**, and the purging cycle is completed.

The thickness of the solid layer remaining after the purging process is designed to prevent liquid/foam material escaping through the ducts **320** during normal production and dispensing operations. The thickness of material required for this purpose depends upon the mechanical properties of the particular material being processed, e.g. the particular polyurethane system. The post purging material thickness is therefore adjustable by the computer system **105** to allow for these variations. Similarly, the threshold value used at step **1109** to determine whether or not a purge cycle should be performed is also adjustable depending upon the mechanical properties of the material being process.

It should be understood that the solid layer of material **601** is used to seal the ducts **320**, and the ducts **320** are used to maintain the layer's thickness within required bounds. If the mixing head **104** is new or if it has been thoroughly cleaned, such that the solid layer **601** is absent, it must first be established before normal operation of the mixing head can take place. To do this, a solid metal plate is attached to the front of the cap **318**, and the output port **319** is closed while the dispensing piston is retracted. A very small quantity (typically fifty grams) of material is then produced, and the dispensing piston is lowered to compress the material into a solid (non-

foam) layer which extends into the ducts **320**. After the layer has had sufficient time to fully react and solidify, the mixing head is ready for normal production.

In an alternative embodiment a separate purging cycle, such as step **1110**, is not required. Instead, each time material has been dispensed and the piston **312** has been brought down onto the solid material layer **601**, the applied pressure is then increased so that said piston is always brought to the same position. i.e. each time after material has been dispensed, a very small quantity of solid material is extruded. In this way, a constant thickness of the solid material layer **601** on the inner surface of cap **318** is maintained.

Figure 14

The second mode of operation of the mixing head **104**, represented by step **808**, and illustrated by *Figure 7A to 7F*, is shown in greater detail in *Figure 14*. Firstly, at step **1401**, a question is asked as to whether the dispensing chamber is ready to dispense, i.e. does it contain material to be dispensed. On the first iteration of step **1401** this question will be answered negatively, but on subsequent iterations it may be answered in the affirmative. If the answer to this question is yes then step **1408** is entered directly, but otherwise the output port **319** is closed at step **1402**. Specifically, the two-way hydraulic valve for the output control rod **321** is energised to close the port **319**.

At step **1403** it is determined whether the solid layer of material **601** has a thickness which is greater than a threshold value, and if so then a purge cycle is performed at step **1404** before step **1405** is entered. (Steps

1403 and **1404** are essentially the same as steps **1109** and **1110**). Otherwise, step **1405** is entered directly from step **1403**. At step **1405** the dispensing piston is moved back, under proportioning valve control, to a required position. This required position has been calculated by the computer system **105** such that the volume of the dispensing chamber **317** is sufficiently large to receive the material which is to be produced.

At step **1406** it is determined whether the high pressure timer, which was started at step **905**, has timed out. This step is repeated until the timer has timed out, and then dispensable material is generated at step **1407**. Step **1407** is substantially the same as step **1106**, but the generated material is stored in the dispensing chamber **317**.

Following material production, a question is asked at step **1408** as to whether a signal has been received indicating that dispensing is required. When such a signal has not been received, step **1408** is repeated. When the dispense signal has been received, material is dispensed at step **1409**. A question is then asked at step **1410** to determine if the current operation is completed. The operation may not be completed because a further production cycle and/or dispensing cycle is required. If the question at step **1410** is answered yes, step **808** is completed. Otherwise step **1401** is re-entered.

Figure 15

The step **1409** of dispensing material is shown in detail in *Figure 15*. Initially at step **1501** the two-way hydraulic directional control valve for the output control rod **321** is de-energised to open the output port **319**. A signal received from the proximity switch **331** then confirms the movement of the

output control rod at step **1502** before material is dispensed at step **1503**. The dispensing is performed by moving forward the piston **312**, at a controlled rate and/or pressure, and for a calculated distance, under the control of the proportioning valve. The distance is, of course, calculated by the computer system **105** such that the required volume of material is dispensed. The dispensed material may be the whole of the material produced at step **1407** or a fraction of it, with the remainder being dispensed during subsequent iterations of step **1409**.

Upon completion of step **1503**, the hydraulic control valve for the output control rod **321** is energised at step **1504**, thus closing the output port **319** to prevent material remaining within chamber **317** from leaking out.

A signal received from the proximity switch confirms closure of the output port at step **1505** to complete step **1409**.

In the majority of preferred applications, the production of material will tend to occur relatively quickly resulting in the dispensing chamber being filled relatively quickly. The material held temporarily within the mixing head will then be dispensed at a relatively slower rate thereby allowing the head to dispense polyurethane foam in environments where a relatively slow flow-rate is required. However, it is appreciated that all of the material contained within the dispensing chamber **317** must be removed while the material remains in a fluid state. Thus, in this way, high quality material may be produced, due to the high pressure mixing, but then dispensed at a relatively lower rate, thereby increasing the number of applications where high pressure mixed material may be deployed.

Figure 16

Automatic operation of the mixing head following power failure is illustrated in *Figure 16*. Upon power failure, using the pressure stored in the accumulator of the power pack: the two-way hydraulic valve for the production piston **301** de-energises and consequently the piston moves forward to stop production (**1601**); the hydraulic valve for the output control rod de-energises and so said rod retracts to open the output port (**1602**); and the dispensing piston is similarly moved fully forward to dispense any material remaining in the mixing head (**1603**). By these means, the mixing head automatically stops production and expels the vast majority of material it contains. Consequently, upon resumption of power, production may be soon restarted.

Figure 17

An alternative mixing head **1704** embodying the present invention is shown in cross section in *Figures 17A* and *17B*. In *Figure 17A* the mixing head is shown with its pistons forward and output port closed as it is between production cycles. *Figures 17B* shows the same head with its pistons retracted and output open as it is when producing and dispensing material simultaneously. This corresponds to the first mode of operation illustrated for mixing head **104** in *Figure 6C.*

Many components of the mixing head **1704** are in common with those of head **104** and so have been similarly labelled. Thus, the mixing head **1704** has a production piston **1701** which, when withdrawn, allows production of material within a production chamber **1705**. Material is dispensed via, or temporarily stored within, a dispensing chamber **1717**.

Material stored within chamber **1717** may be dispensed by a dispensing piston **1712** through an output port **1719** which may be closed by lowering an output control rod **1721**. In contrast to the main embodiment, the production chamber is connected to the dispensing chamber by a cylindrical passage **1751** which contains a piston **1752**.

During production cycles, the piston **1752** is retracted immediately prior to production piston **1701**, and then moved forward immediately after production piston **1701** has shut off production. Otherwise, the mixing head **1704** operates in a similar manner to mixing head **104**. It should therefore be understood that the mixing head **1704** can operate in the two modes described with reference to mixing head **104**.

Under very high material injection pressures, the piston **1752** provides an additional barrier between the material in dispensing chamber **1717** and the jets located within the production chamber **1705**.

In conclusion, the preferred embodiments allow the rate at which material is mixed (to initiate chemical reaction) to be separated from the rate at which the output material is dispensed. Experimentation suggests that the material may be held within the dispensing chamber **317** for a maximum period of twenty seconds. The embodiments allow material to be dispensed at low rates (for example at three grams per second or lower) using equipment that does not need to be cleaned but would normally produce output material at a rate of fifty grams per second. Low dispensing rates usually require low pressure systems to be used which use organic solvents in a cleaning cycle usually taking a minimum of forty five seconds representing system downtime. Thus, the preferred embodiment removes the need for hazardous cleansing materials to be used while at the same

time reducing downtimes. This benefits industries such as the previously described manufacture of engine filters where a typical facility may produce of the order of one thousand filters per hour.

The rate of dispensing in the preferred embodiment is fully detached from the rate of mixing therefore the output rate is very flexible. Thus, a single machine may offer many different output flow-rates by simple modifications to the dimensions of the output dispensing chamber.

A further advantage of the preferred embodiment is that the pressure at which the material is dispensed from the output port **319** is not related to the pressure encountered within the production chamber **301**. Thus, under some circumstances the pressure at which the material is released through port **319** may be greater than the pressure encountered within the production chamber **301** during foam formation. The pressure encountered by the dispensing chamber **317** is not felt by pumps **103** when valves **502** and **552** are in their closed condition while material is being dispensed.

During operation, the volume of the output dispensing chamber is effectively variable given that the extent to which dispensing piston **312** is raised may be adjusted.

The provision of the output control rod **321** ensures that there is no leakage when material is not required.

The ability to adjust the rates at which material is dispensed provides an opportunity for the dispensed rate to be controlled and adjusted within a particular dispensing operation. Thus, for example, when producing a foam bead it would be possible for part of the bead to have a larger area by increasing the rate at which the material is released as an alternative to reducing the speed of a robotic movement. This greater flexibility may

increase production speeds and may reduce mechanical constraints placed upon robotic operations.

In a standard high pressure system, a mixing head is required to open and close at each pouring of material. A start of mixing and an end of mixing create situations of poor impingement due to the deflecting effect created by the blind end section of the grooves in the production piston. Thus, situations often occur in which the start of a flow and the end of a flow are sub-standard and this may result in products being rejected. In the present preferred embodiment, material created at the start of material production and at the end of material production are mixed together within the output dispensing chamber such that material released from the output dispensing chamber **317** is substantially homogeneous. Furthermore the mixing is assisted by the mixture colliding with the output control rod **321**.

Standard high pressure mixing heads perform a finite number of cycles before periodic maintenance is required. Typically, a mixing head will perform five thousand to five hundred thousand cycles depending upon the type of materials being processed. In some situations relatively short bursts of activity are required to produce relatively small volumes and this in turn will lead to a shorter active life. The present embodiment allows a number of activations within the production chamber to be reduced given that more material may be produced on each activation and then held temporarily within the output dispensing chamber.

Claims

1. Apparatus for dispensing material produced by a chemical reaction between a first chemical reagent and a second chemical reagent, comprising:

injection means configured to produce a jet of said first chemical reagent and a jet of said second chemical reagent such that said jets collide to produce said material;

a storage chamber arranged to provide temporary storage space for the material, said storage chamber having an inlet for receiving said material, and an outlet for dispensing the material; and

a closing device moveable between a first position in which the material is prevented from passing through said outlet while allowing material to be received into the storage chamber through the inlet and a second position in which the material is allowed to be dispensed through said outlet.

2. Apparatus according to claim 1, wherein said storage chamber has a dispensing piston configured to dispense said material from said storage chamber.

3. Apparatus according to claim 2, wherein said apparatus has control means configured to control the rate at which said dispensing piston dispenses said material.

4. Apparatus according to claim **2**, wherein said apparatus has control means configured to control the movement of said dispensing piston such that defined portions of the stored material are dispensed.

5. Apparatus according to any of claims **2** to **4**, wherein said apparatus has a position sensing means configured to provide a measure of the position of said dispensing piston along said storage chamber.

6. Apparatus according to any of claims **2** to **5**, wherein said dispensing piston for dispensing said material has: a first surface acted upon by hydraulic fluid; and a second surface acting upon said material which is smaller than said first surface, whereby the pressure applied to said material is larger than the hydraulic pressure applied to said piston.

7. Apparatus according to claim **6**, wherein said second surface is less than half of the area of the first surface.

8. Apparatus according to any of claims **2** to **7**, wherein said storage chamber has a wall defining a plurality of orifices and said dispensing piston is configured to extrude built-up reacted material through said orifices.

9. Apparatus according to claim **8**, wherein said orifices are configured to be blocked by a layer of solidified material while fluid material is dispensed through said outlet.

10. Apparatus according to claim **9**, wherein a portion of said layer is regularly extruded during dispensing operations.

11. *Apparatus according to claim* **8**, *wherein said orifices are* defined in a wall having a plurality of raised edges to assist extrusion through said orifices.

12. Apparatus according to claim **8**, wherein said orifices are defined in a wall having a cooling means for cooling material within said chamber.

13. Apparatus according to any of claims **1** to **12**, wherein said closing device is a rod having an end which is moveable into said outlet to provide said first position and which is retractable into said storage chamber to provide said second position.

14. Apparatus according to any of claims **1** to **13**, wherein said material is produced intermittently at a first rate, and said material is dispensed at a second different rate.

15. Apparatus according to claim **14**, wherein said first rate is higher than the second rate.

16. Apparatus according to any of claims **1** to **15**, wherein said dispensed material is polyurethane produced by reacting a diol as the first chemical reagent with a diisocyanate as the second chemical reagent.

17. Apparatus according to any of claims **1** to **16**, wherein said apparatus is configured to locate said closing device in said first position during material production, and subsequently locate said closing device in said second position during dispensing.

18. Apparatus according to any of claims **1** to **16**, wherein said apparatus has:

a first mode of operation in which it is configured to locate said closing device in said first position during material production, and subsequently locate said closing device in said second position during dispensing; and

a second mode of operation in which said apparatus is configured to locate said closing device in said second position during production of said material, such that material is dispensed during production.

19. Apparatus according to any of claims **1** to **18**, including input interface means for receiving command instructions from a programmable control system.

20. Apparatus according to any of claims **1** to **19,** wherein said injection means are arranged such that said jets collide in a production chamber having a piston for controlling said reaction, and said material is received at said storage chamber from said production chamber via a passage which is closeable by a third piston.

21. A method of dispensing material produced by a chemical reaction between a first chemical reagent and a second chemical reagent, said method comprising the steps of:

injecting a jet of said first chemical reagent and a jet of said second chemical reagent such that said jets collide to produce said material;

temporarily storing the material in a chamber having an inlet for receiving said material, and an outlet for dispensing the material; and

moving a closing device between a first position in which the material is prevented from passing through said outlet and a second position in which the material is allowed to be dispensed through said outlet.

22. A method according to claim **21**, wherein said storage chamber has a piston said material is dispensed from said storage chamber by moving said piston.

23. A method according to claim **22**, wherein the rate at which said piston dispenses said material is controlled.

24. A method according to claim **22**, wherein movement of said piston is controlled such that defined portions of the stored material are dispensed.

25. A method according to any of claims **22** to **24**, wherein said piston for dispensing said material has a first surface acted upon by hydraulic fluid, and a second surface acting upon said material which is

smaller than said first surface, whereby pressure is applied to said material which is larger than the hydraulic pressure applied to said piston.

26. A method according to claim **25**, wherein said second surface is less than half of the area of the first surface.

27. A method according to any of claims **22** to **26**, wherein said storage chamber has a wall defining a plurality of orifices and said piston is used to extrude built-up reacted material through said orifices.

28. A method according to claim **27**, wherein said orifices are blocked by a layer of solidified material while material in a fluid state is dispensed through said outlet.

29. A method according to claim **28**, wherein a portion of said layer is regularly extruded during dispensing operations.

30. A method according to any of claims **21** to **29**, wherein said material is produced at a first rate, and said material is dispensed at a second different rate.

31. A method according to claim **30**, wherein said first rate is higher than the second rate.

32. A method according to any of claims **21** to **31**, wherein said dispensed material is polyurethane produced by reacting a diol as the first

chemical reagent with a diisocyanate as the second chemical reagent.

33. A method according to any of claims **21** to **32**, wherein said closing device is located in said first position during material production, and said closing device is located in said second position during dispensing.

34. A method according to any of claims **21** to **33**, wherein material is dispensed:

in a first mode of operation by locating said closing device in said first position during material production, and subsequently locating said closing device in said second position during dispensing; and

in a second mode of operation by locating said closing device in said second position during production of said material, such that material is dispensed during production.

35. A method according to any of claims **21** to **34**, in which command instructions are received at an input interface of a programmable control system.

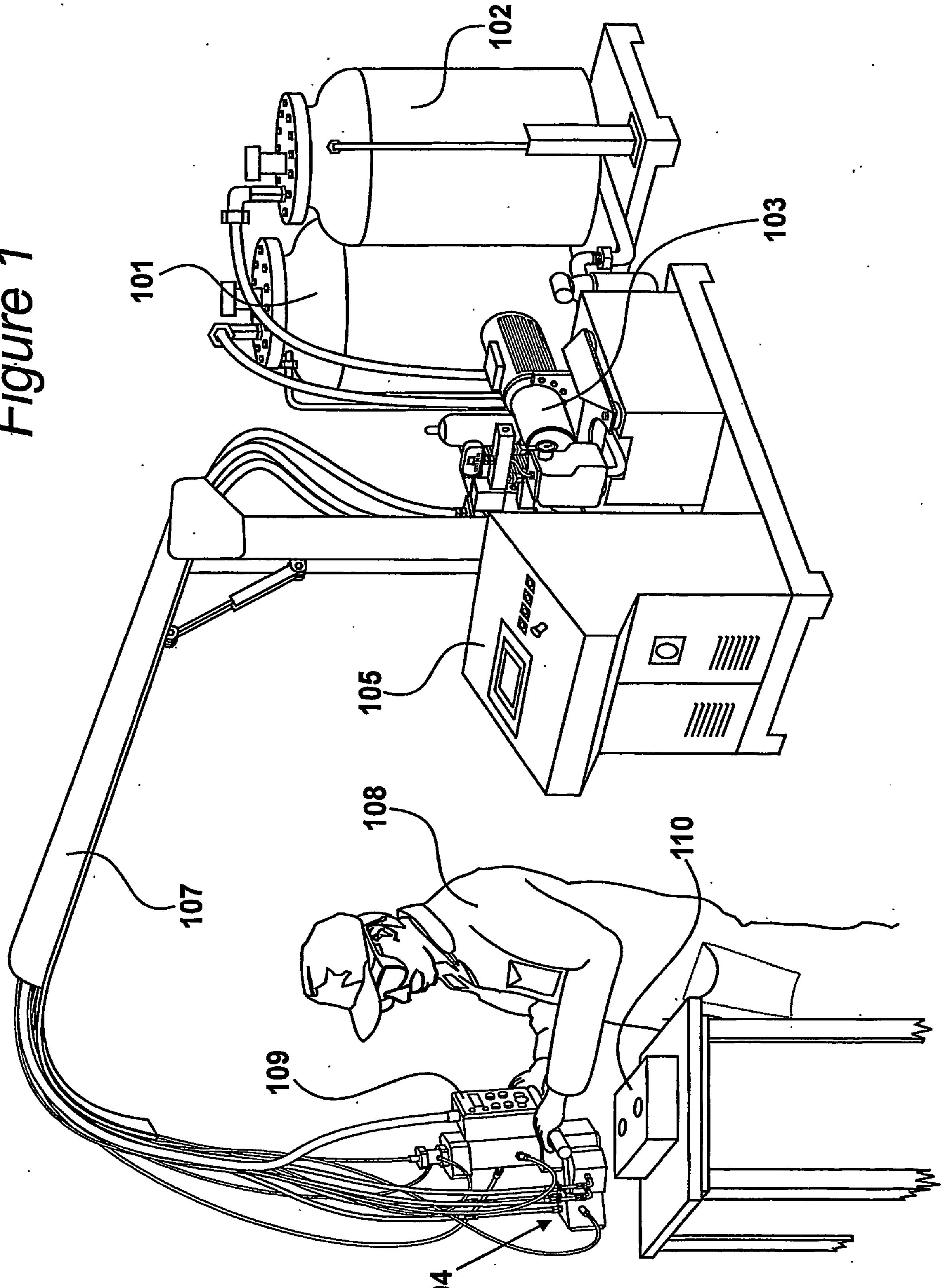


Figure 1

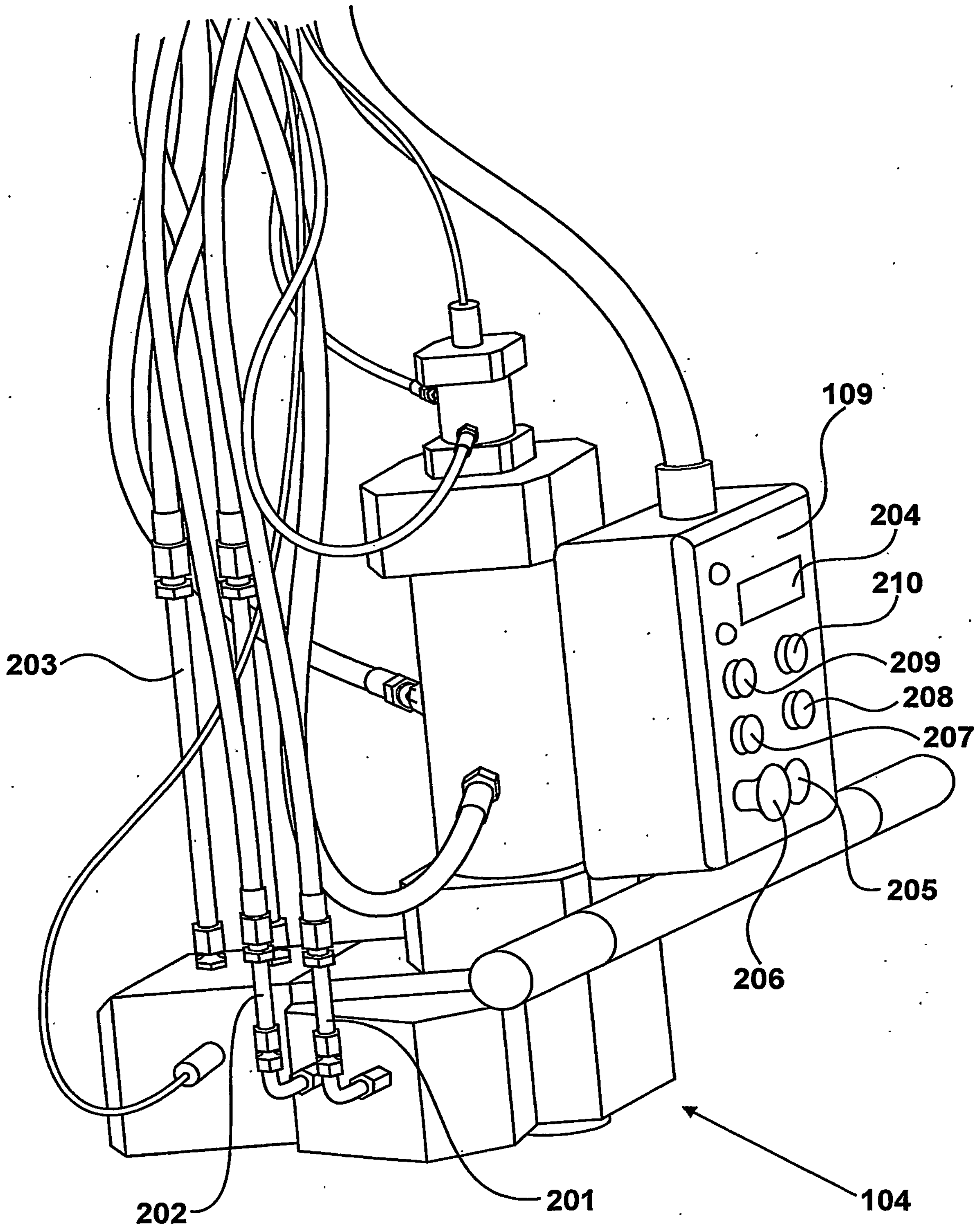
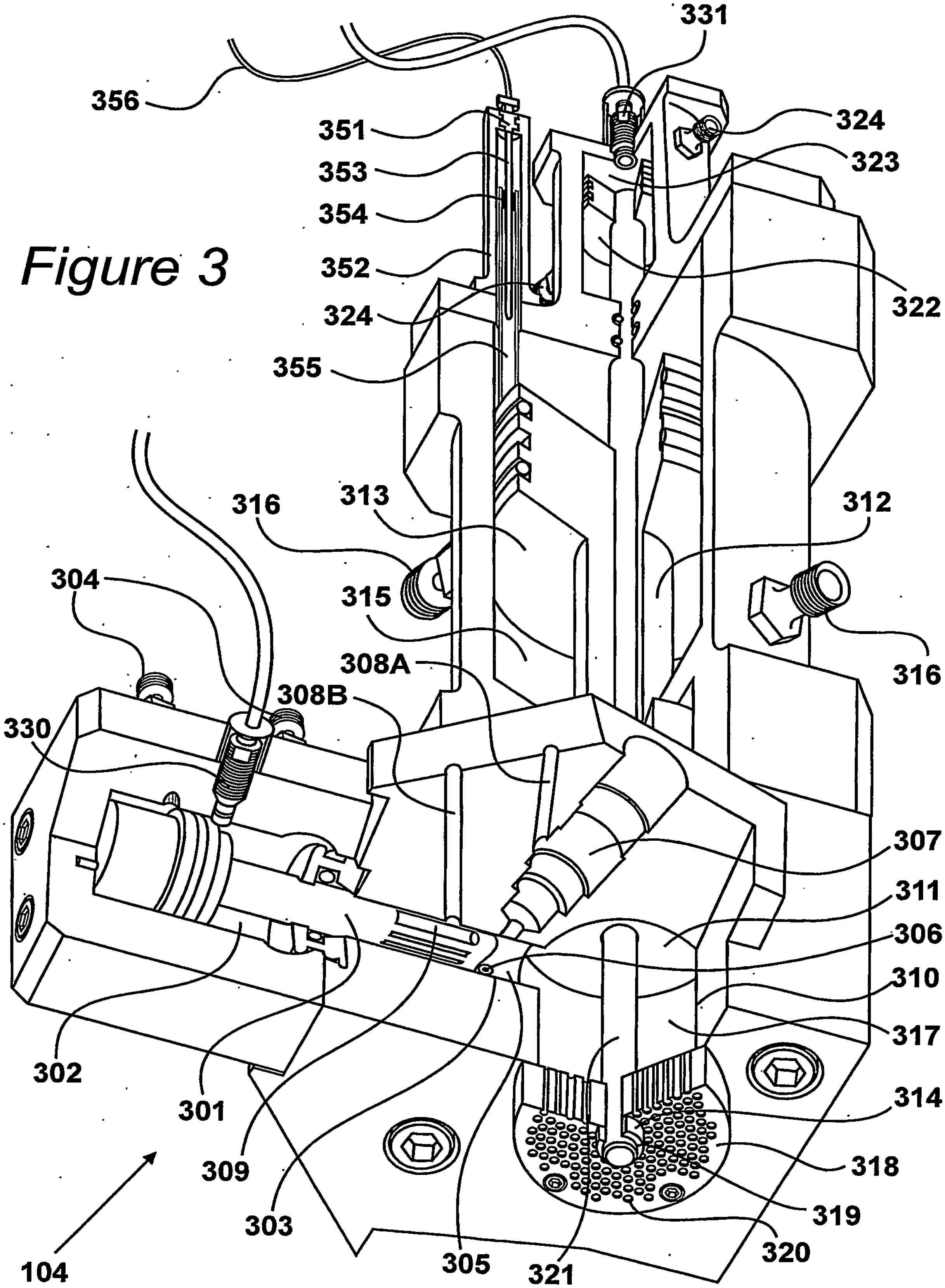


Figure 2

Figure 3



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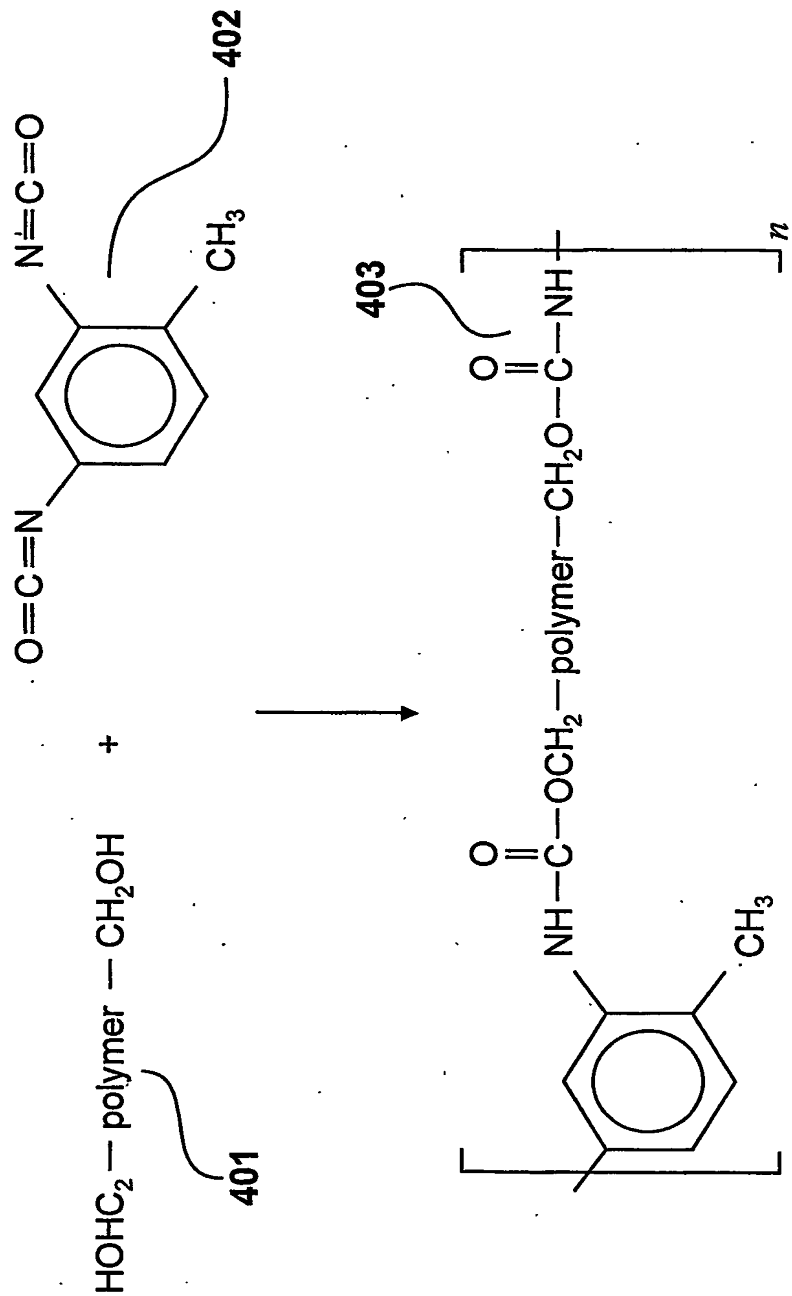
104



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+
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N=C=O
CH3
NH—C—OCH2—polymer—CH2O—C—NH
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CH3
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401
402
403

Figure 4

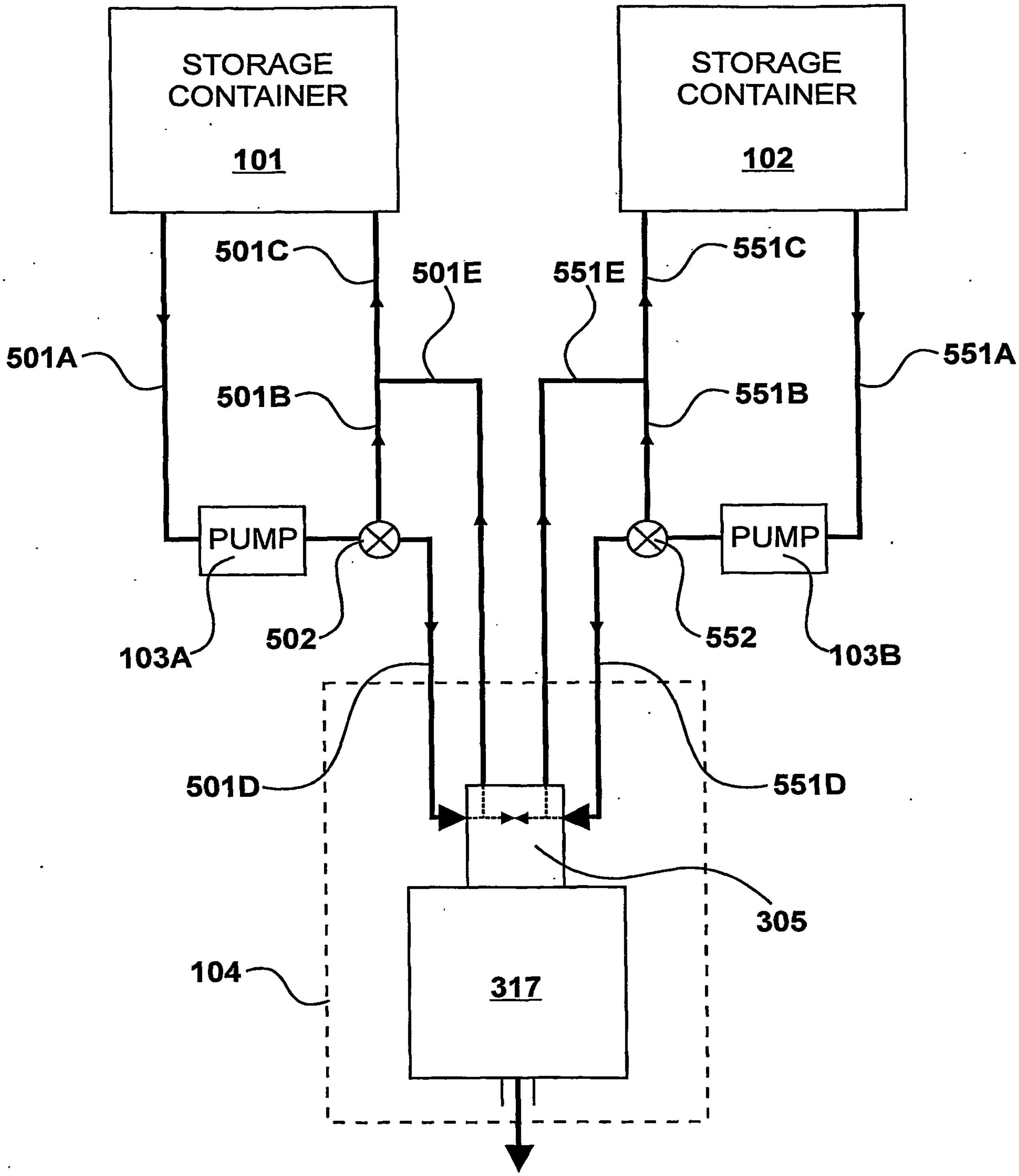
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Figure 5

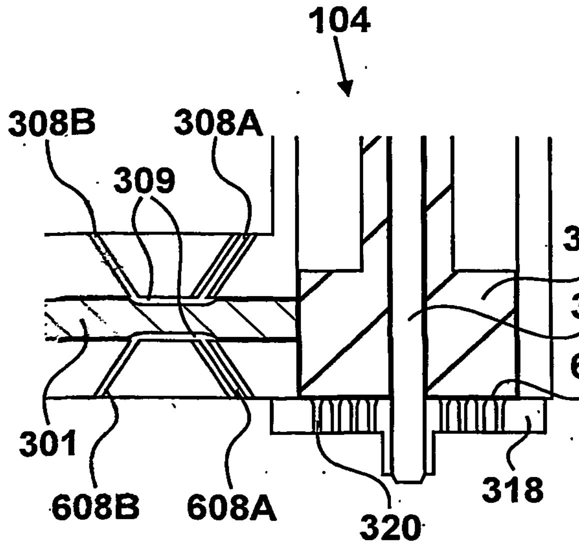


Figure 6A

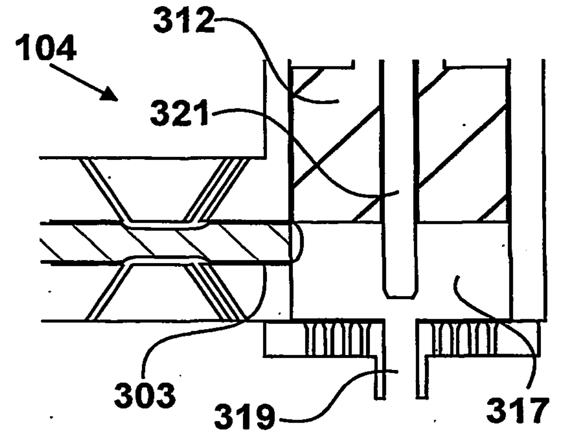


Figure 6B

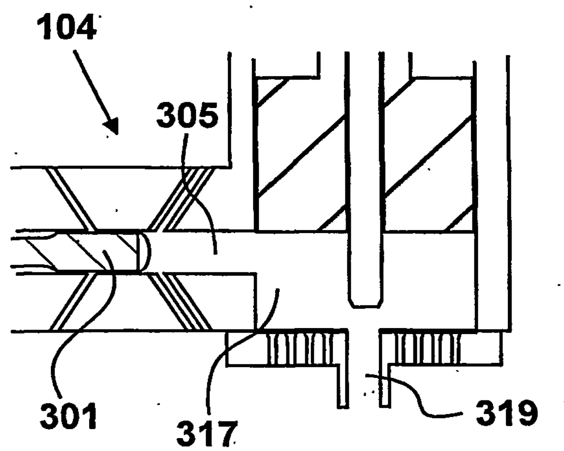


Figure 6C

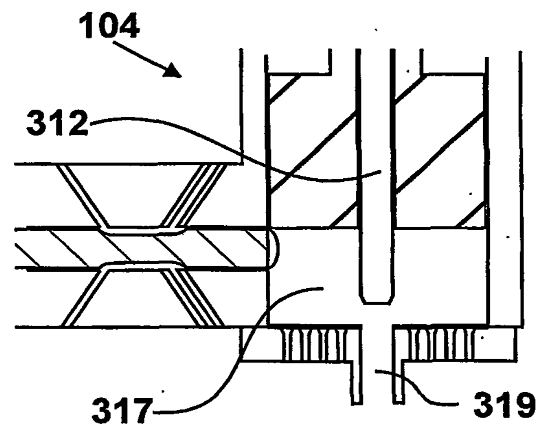


Figure 6D

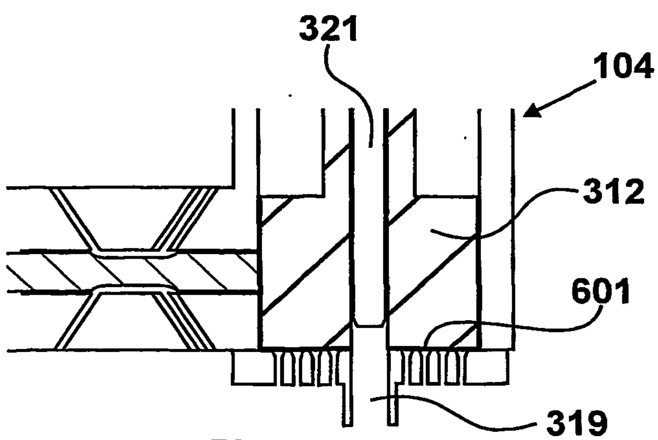


Figure 6E

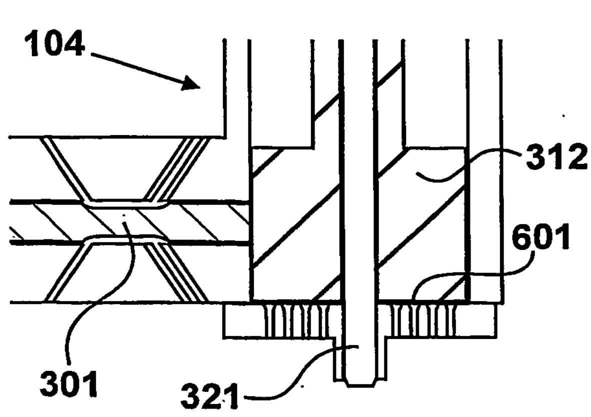


Figure 7A

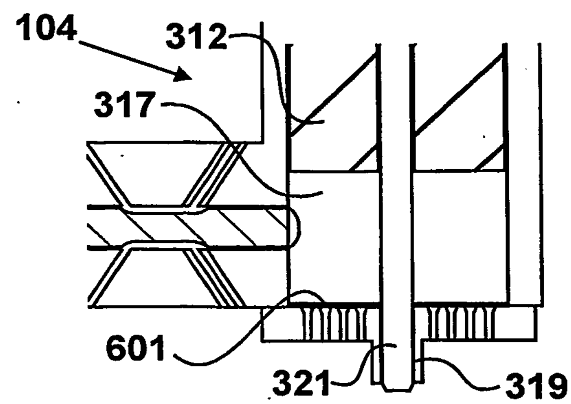


Figure 7B

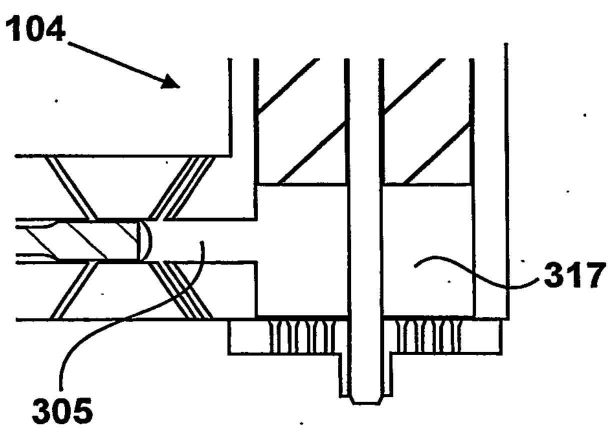


Figure 7C

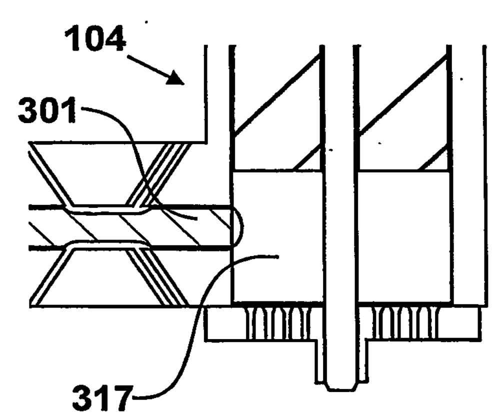


Figure 7D

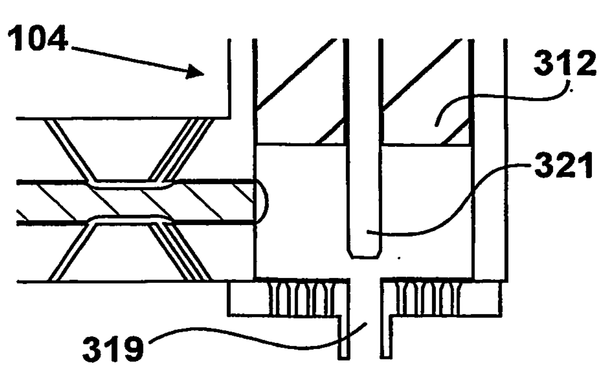


Figure 7E

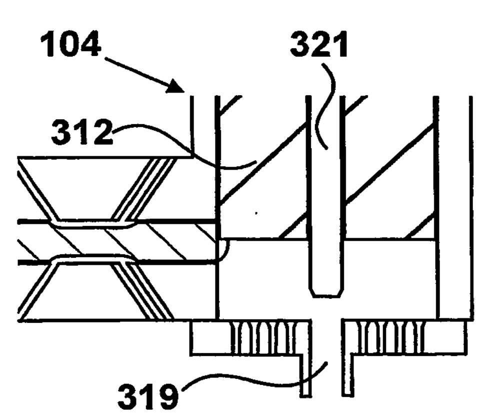


Figure 7F

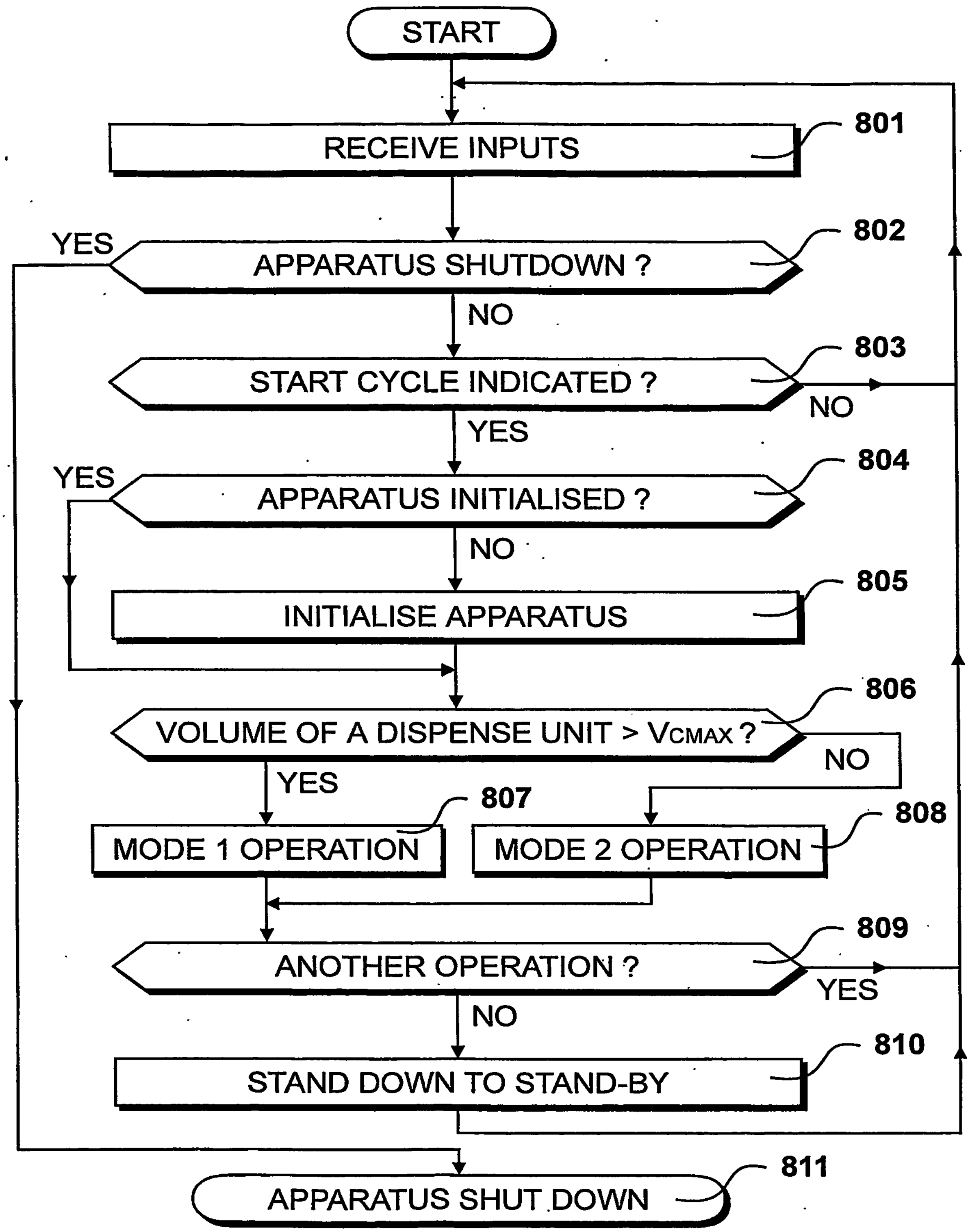

START
RECEIVE INPUTS
801
APPARATUS SHUTDOWN ?
802
YES
NO
START CYCLE INDICATED ?
803
NO
YES
APPARATUS INITIALISED ?
804
YES
NO
INITIALISE APPARATUS
805
VOLUME OF A DISPENSE UNIT > VCMAX ?
806
NO
YES
MODE 1 OPERATION
807
MODE 2 OPERATION
808
ANOTHER OPERATION ?
809
YES
NO
STAND DOWN TO STAND-BY
810
APPARATUS SHUT DOWN
811

Figure 8

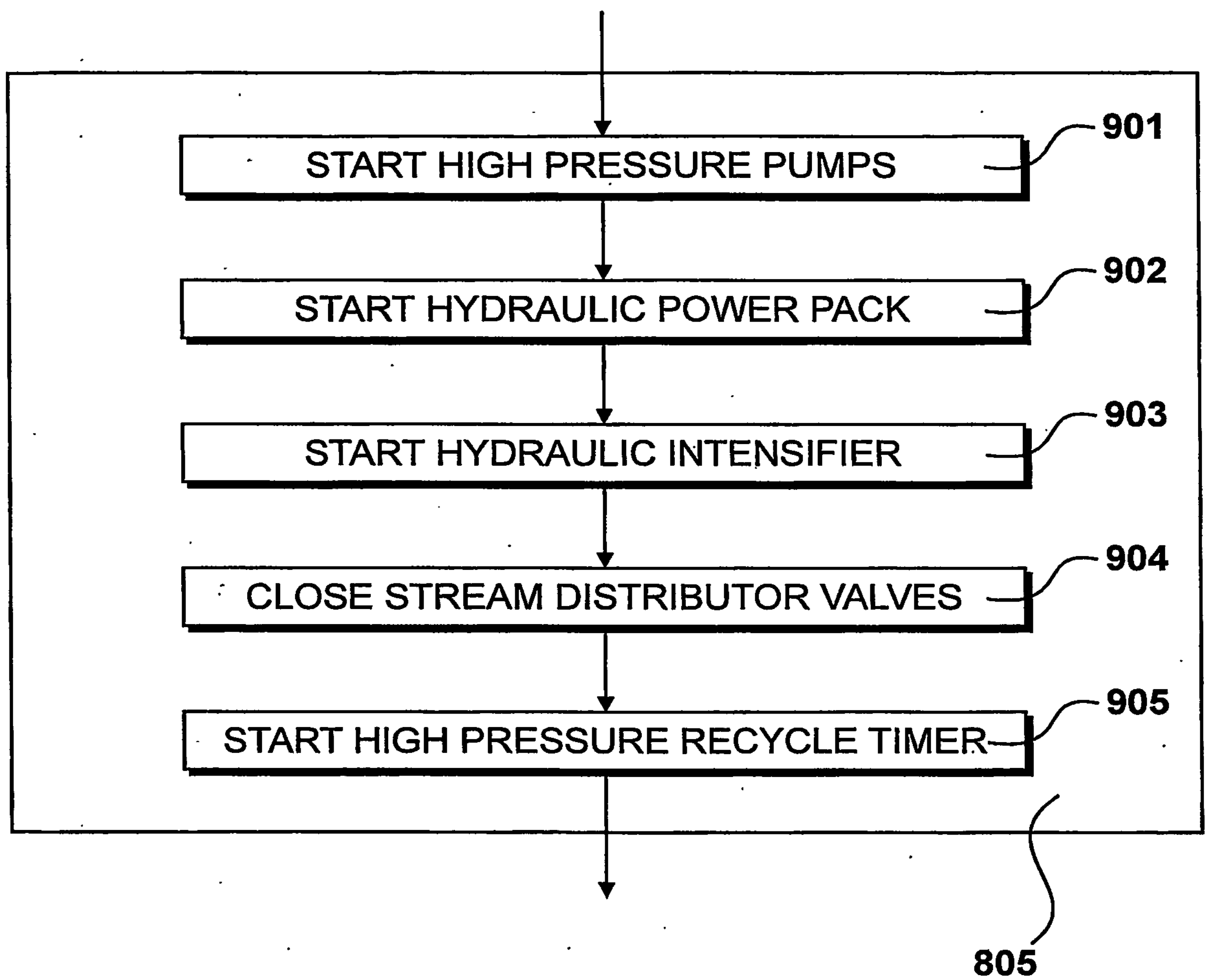
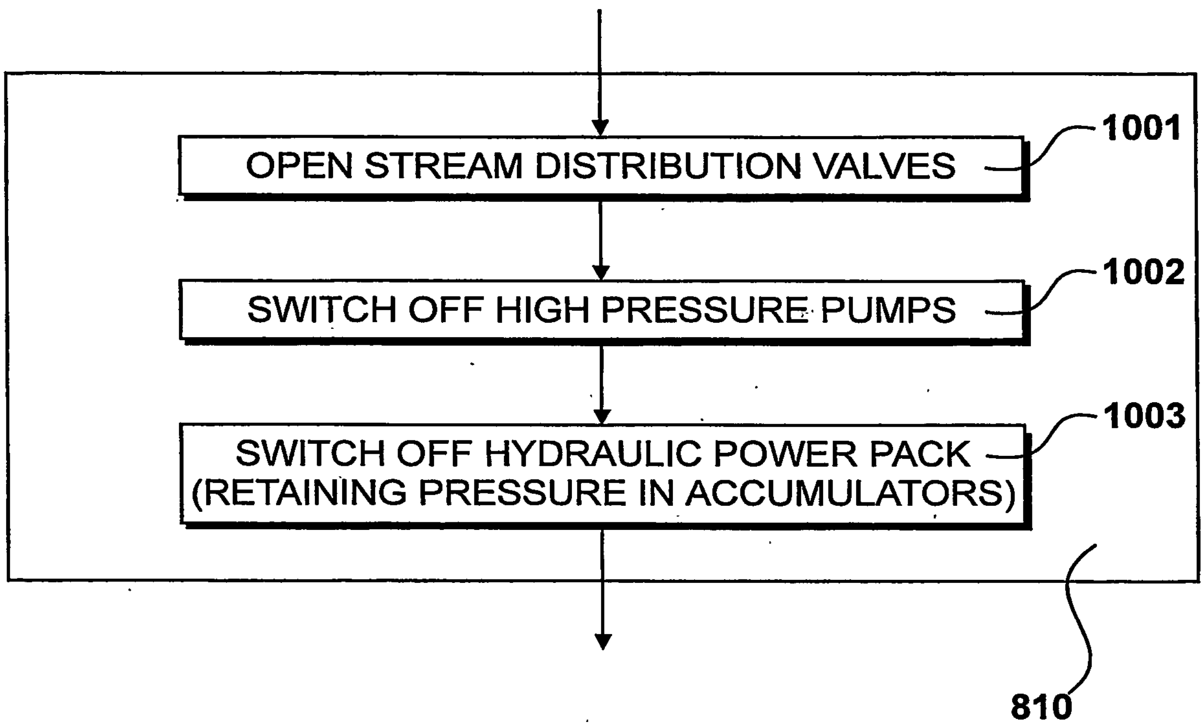

START HIGH PRESSURE PUMPS
901
START HYDRAULIC POWER PACK
902
START HYDRAULIC INTENSIFIER
903
CLOSE STREAM DISTRIBUTOR VALVES
904
START HIGH PRESSURE RECYCLE TIMER
905
805

Figure 9



OPEN STREAM DISTRIBUTION VALVES
1001
SWITCH OFF HIGH PRESSURE PUMPS
1002
SWITCH OFF HYDRAULIC POWER PACK (RETAINING PRESSURE IN ACCUMULATORS)
1003
810

Figure 10

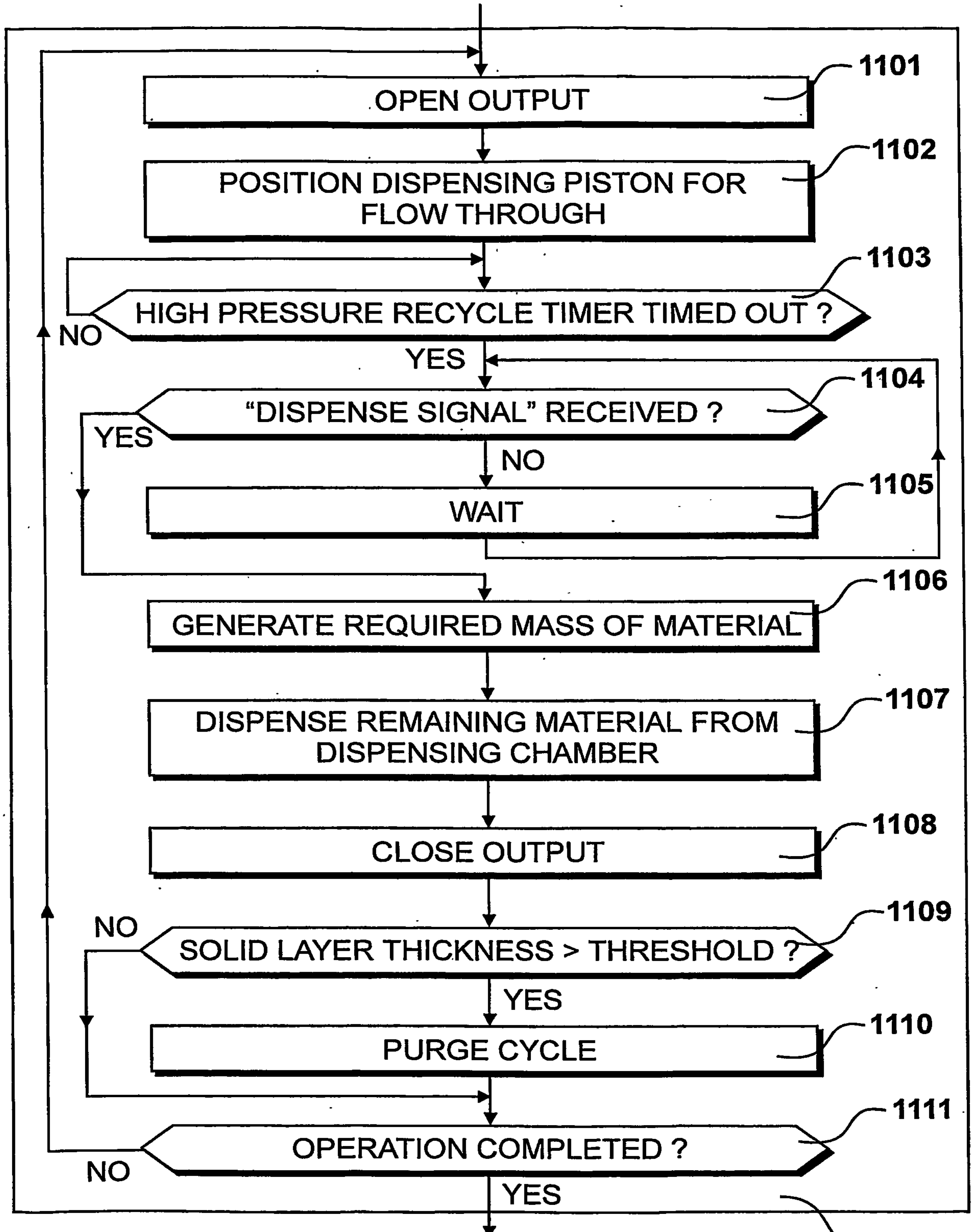

OPEN OUTPUT
1101
POSITION DISPENSING PISTON FOR FLOW THROUGH
1102
HIGH PRESSURE RECYCLE TIMER TIMED OUT ?
1103
NO
YES
"DISPENSE SIGNAL" RECEIVED ?
1104
YES
NO
WAIT
1105
GENERATE REQUIRED MASS OF MATERIAL
1106
DISPENSE REMAINING MATERIAL FROM DISPENSING CHAMBER
1107
CLOSE OUTPUT
1108
SOLID LAYER THICKNESS > THRESHOLD ?
1109
NO
YES
PURGE CYCLE
1110
OPERATION COMPLETED ?
1111
NO
YES
807

Figure 11

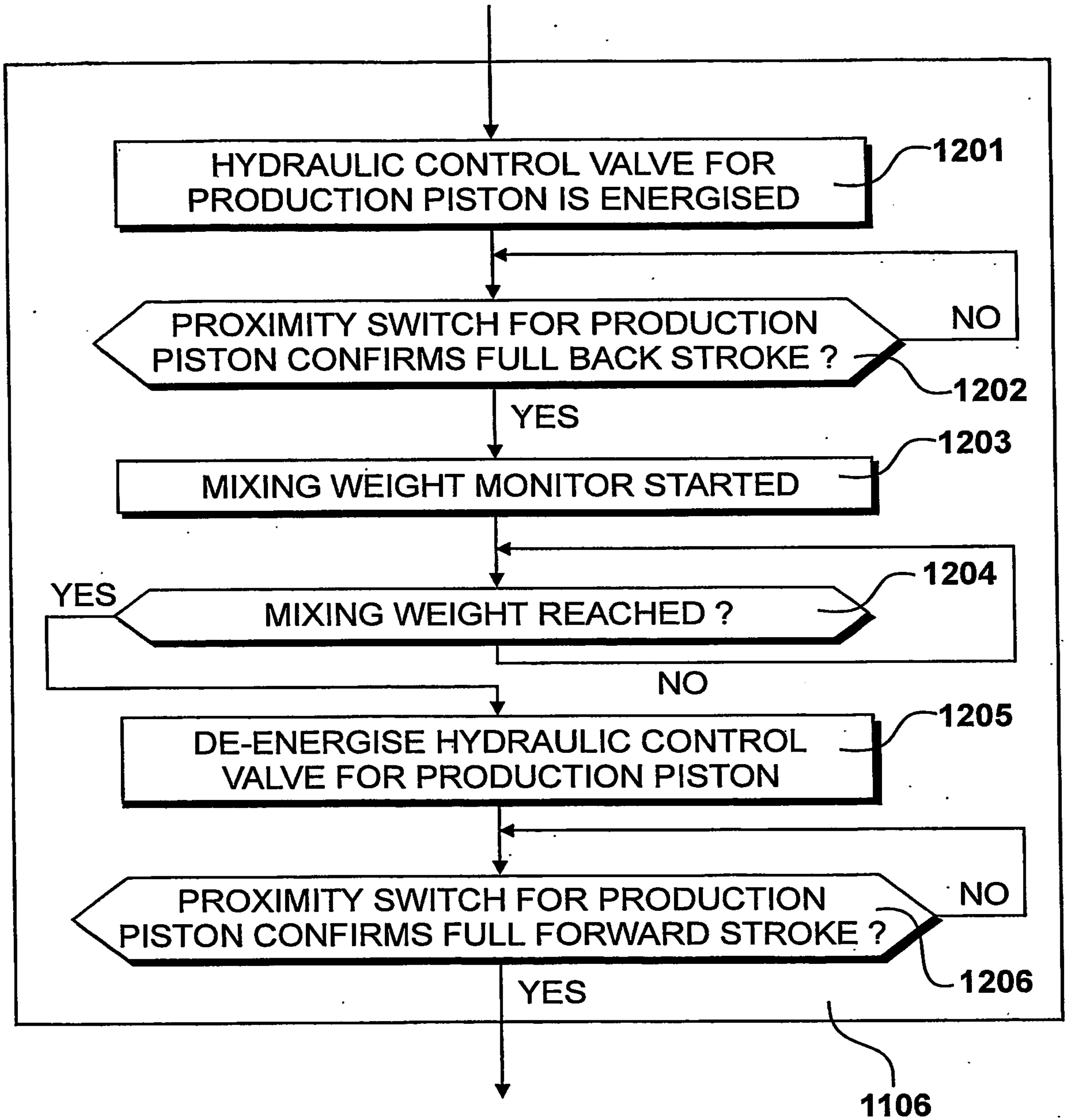

HYDRAULIC CONTROL VALVE FOR PRODUCTION PISTON IS ENERGISED
1201
PROXIMITY SWITCH FOR PRODUCTION PISTON CONFIRMS FULL BACK STROKE ?
NO
1202
YES
MIXING WEIGHT MONITOR STARTED
1203
MIXING WEIGHT REACHED ?
1204
YES
NO
DE-ENERGISE HYDRAULIC CONTROL VALVE FOR PRODUCTION PISTON
1205
PROXIMITY SWITCH FOR PRODUCTION PISTON CONFIRMS FULL FORWARD STROKE ?
NO
1206
YES
1106

Figure 12

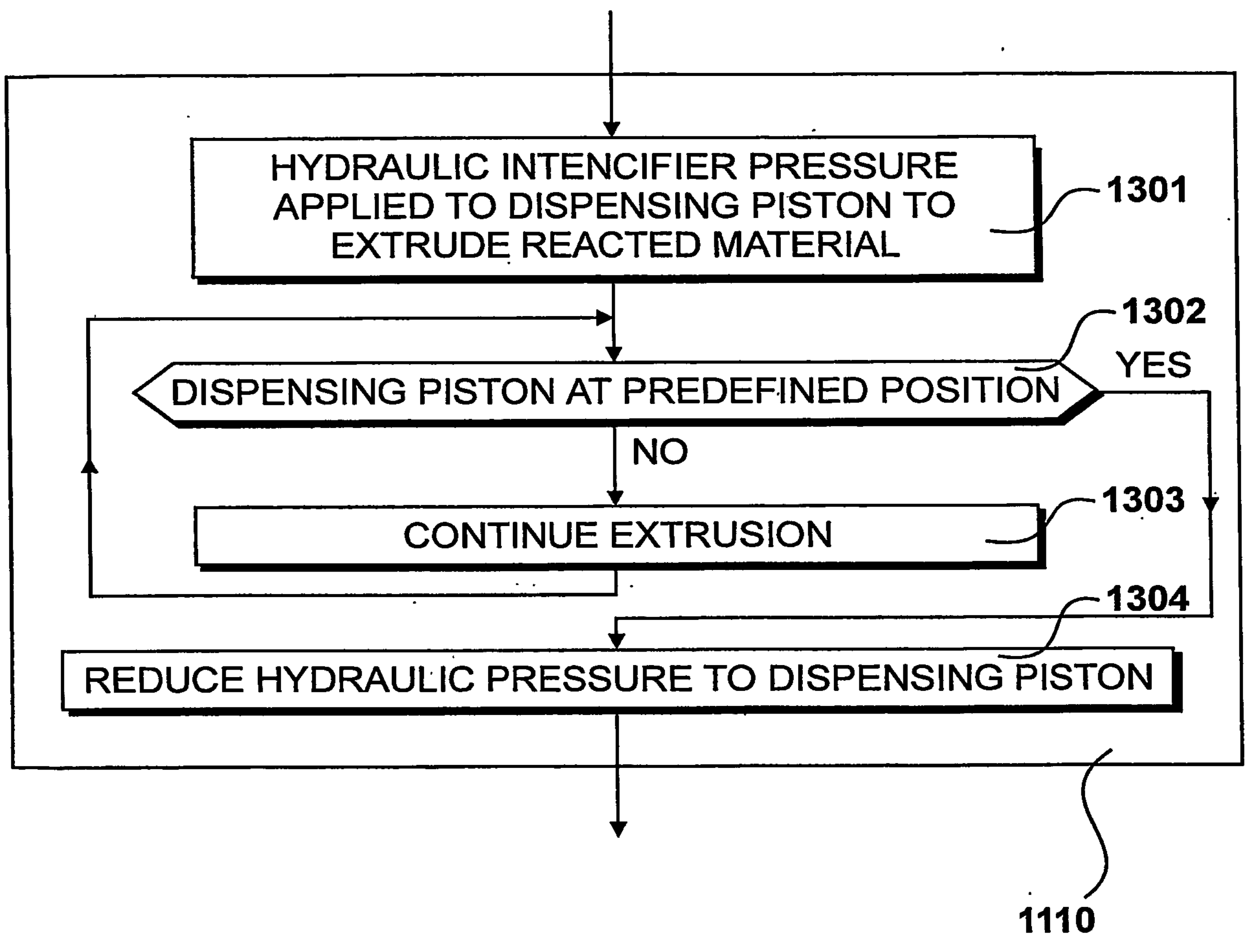

HYDRAULIC INTENCIFIER PRESSURE APPLIED TO DISPENSING PISTON TO EXTRUDE REACTED MATERIAL
1301
1302
YES
DISPENSING PISTON AT PREDEFINED POSITION
NO
1303
CONTINUE EXTRUSION
1304
REDUCE HYDRAULIC PRESSURE TO DISPENSING PISTON
1110

Figure 13

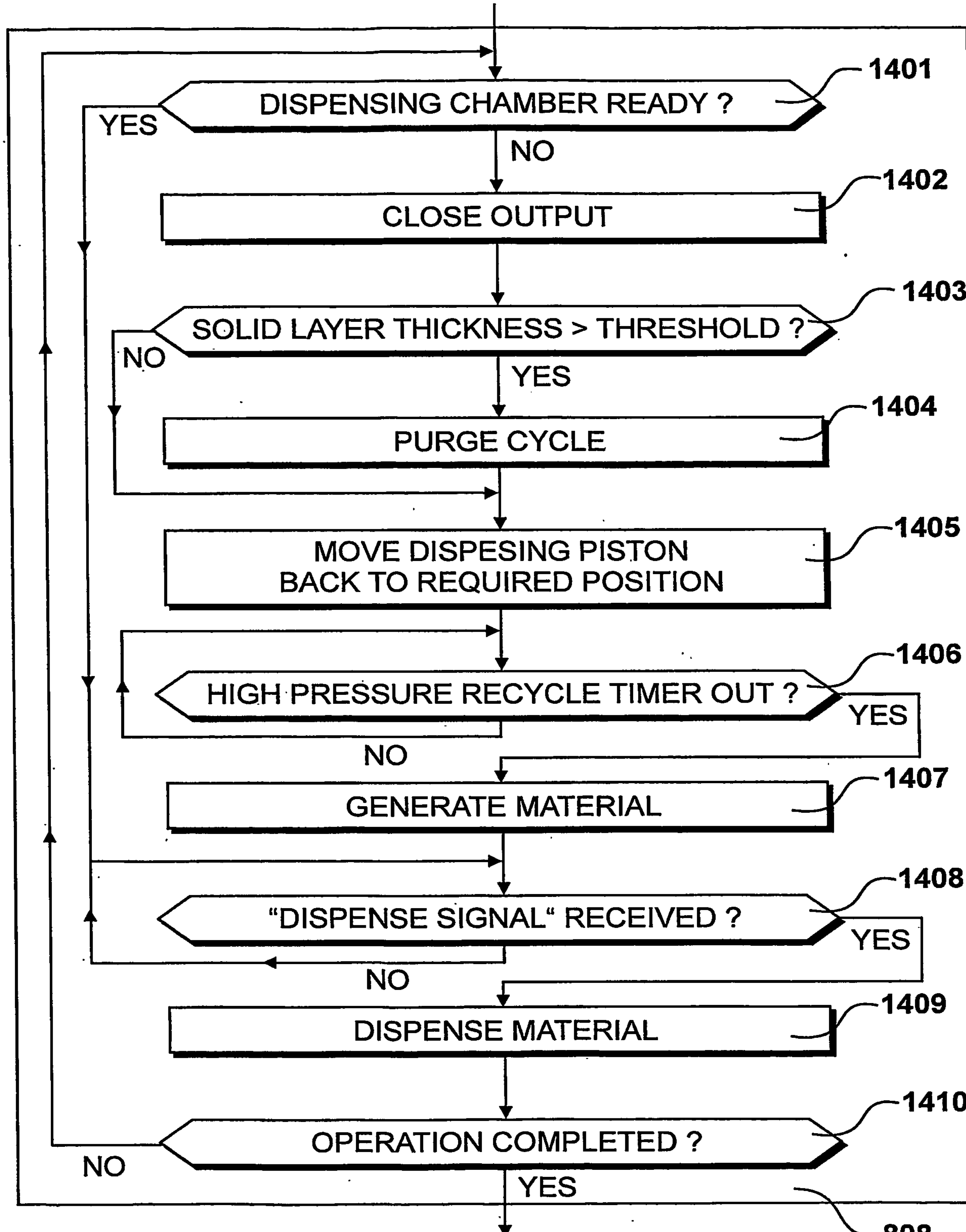

DISPENSING CHAMBER READY ?
1401
YES
NO
CLOSE OUTPUT
1402
SOLID LAYER THICKNESS > THRESHOLD ?
1403
NO
YES
PURGE CYCLE
1404
MOVE DISPESING PISTON
BACK TO REQUIRED POSITION
1405
HIGH PRESSURE RECYCLE TIMER OUT ?
1406
YES
NO
GENERATE MATERIAL
1407
"DISPENSE SIGNAL" RECEIVED ?
1408
YES
NO
DISPENSE MATERIAL
1409
OPERATION COMPLETED ?
1410
NO
YES
808

Figure 14

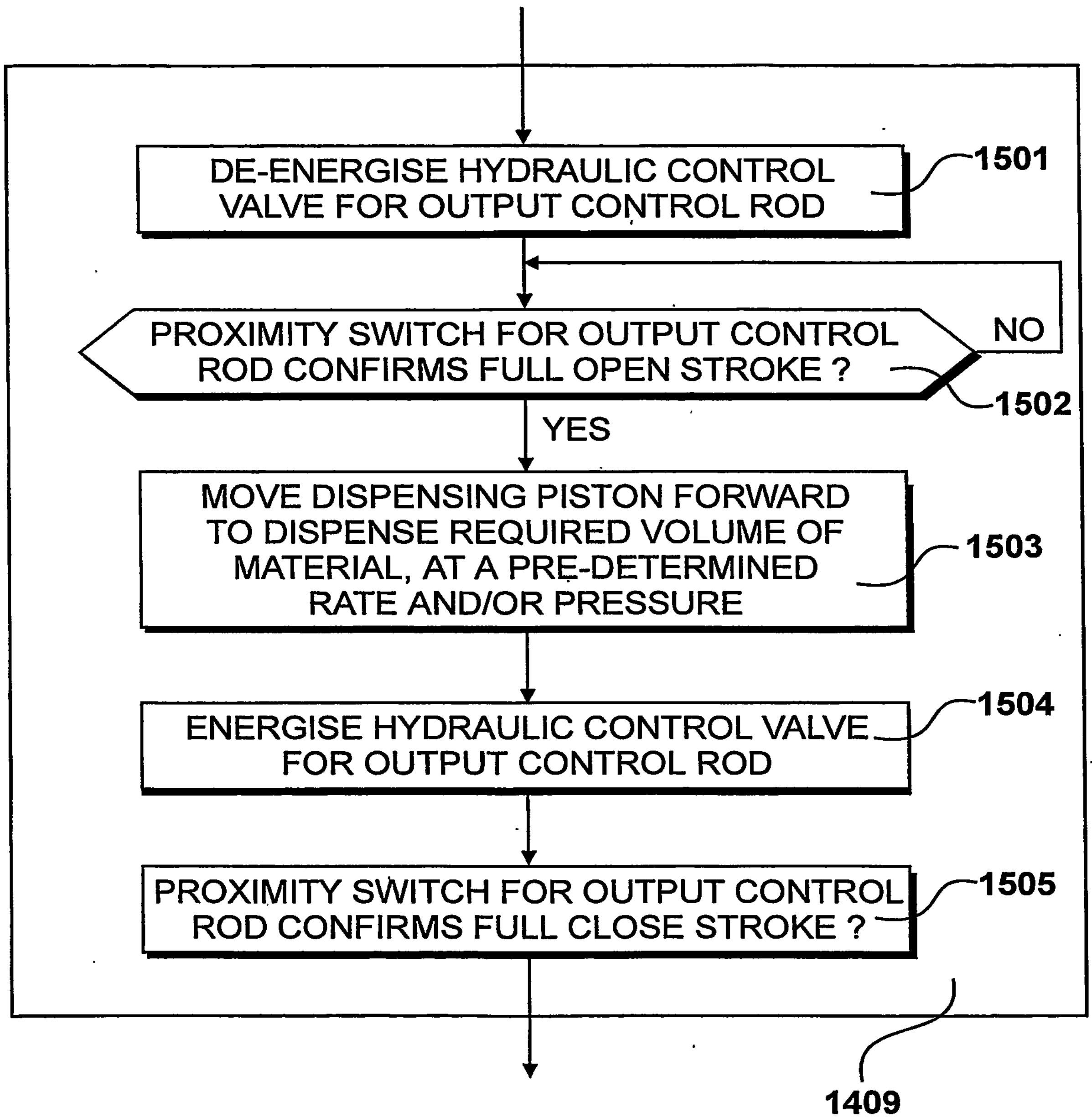

DE-ENERGISE HYDRAULIC CONTROL VALVE FOR OUTPUT CONTROL ROD
1501
PROXIMITY SWITCH FOR OUTPUT CONTROL ROD CONFIRMS FULL OPEN STROKE ?
NO
1502
YES
MOVE DISPENSING PISTON FORWARD TO DISPENSE REQUIRED VOLUME OF MATERIAL, AT A PRE-DETERMINED RATE AND/OR PRESSURE
1503
ENERGISE HYDRAULIC CONTROL VALVE FOR OUTPUT CONTROL ROD
1504
PROXIMITY SWITCH FOR OUTPUT CONTROL ROD CONFIRMS FULL CLOSE STROKE ?
1505
1409

Figure 15

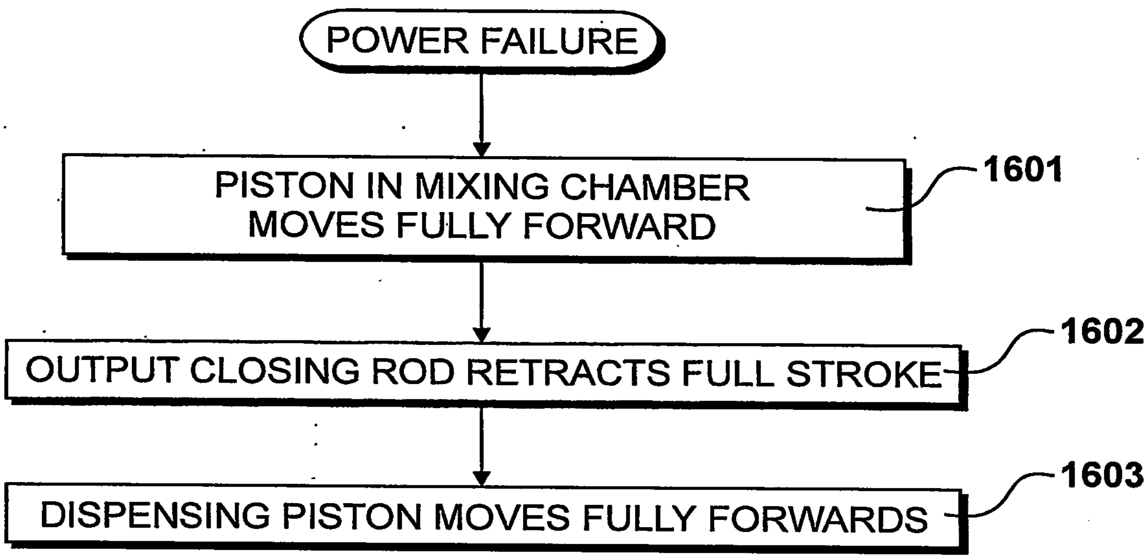

POWER FAILURE
PISTON IN MIXING CHAMBER MOVES FULLY FORWARD
1601
OUTPUT CLOSING ROD RETRACTS FULL STROKE
1602
DISPENSING PISTON MOVES FULLY FORWARDS
1603

Figure 16

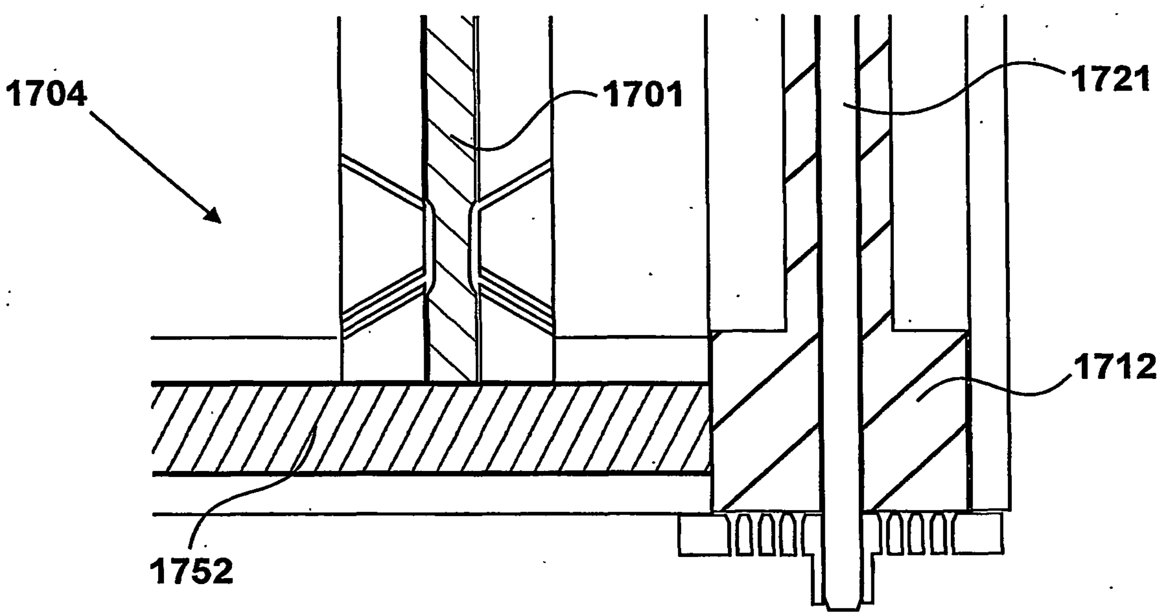


Figure 17A

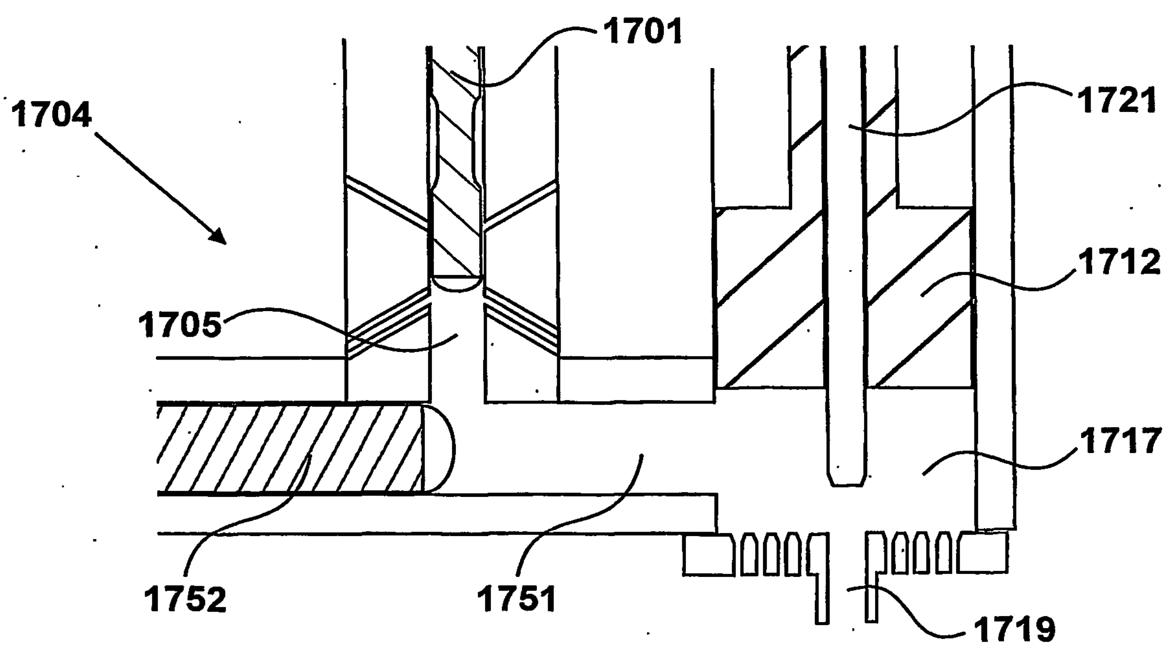


Figure 17B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/01427

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29B7/76 B01F5/02 B01F15/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29B B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 277 567 A (BAUER ADOLF ET AL) 11 January 1994 (1994-01-11) column 2, line 62 -column 3, line 10 column 3, line 34 - line 41 column 5, line 46 - line 49 column 5, line 61 - line 63 column 6, line 11 - line 34 column 7, line 15 - line 60 column 8, line 51 -column 9, line 10; figures 1,4 ---	1-3,6,7, 14-18, 20-23, 25,26, 30-34

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 July 2003	24/07/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fageot, P

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 057 548 A (BAUER ADOLF ET AL) 15 October 1991 (1991-10-15) column 1, line 8 - line 20 column 1, line 65 -column 2, line 16 column 2, line 54 - line 68 column 3, line 48 -column 4, line 65; figures	1-3,6,7, 14-17, 20-23, 25,26, 30-33
A	US 3 975 128 A (SCHLUTER KLAUS) 17 August 1976 (1976-08-17) abstract; figures	1-3,6,7, 14-16, 20-23, 25,26, 30-32

INTERNATIONAL SEARCH REPORT

In[illegible]n on patent family members

Internati[illegible]plication No
PCT/GB 03/01427

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5277567 A	11-01-1994	DE 4009465 A1	26-09-1991
		AT 98150 T	15-12-1993
		EP 0447883 A1	25-09-1991
		ES 2047351 T3	16-02-1994
		JP 3202252 B2	27-08-2001
		JP 4221611 A	12-08-1992
US 5057548 A	15-10-1991	DE 3626990 A1	18-02-1988
		AT 54089 T	15-07-1990
		EP 0255895 A2	17-02-1988
		JP 63049412 A	02-03-1988
		US 4898714 A	06-02-1990
US 3975128 A	17-08-1976	DE 2327269 A1	05-12-1974
		FR 2231490 A1	27-12-1974
		GB 1459651 A	22-12-1976